TECHNICAL REPORT

74-14-FL

EVALUATION OF SULFITE TREATMENT OF RED TART CHERRIES, GREEN BELL PEPPERS AND APPLES FOR DEHYDRATION

by

Robert L. LoBelle and Terry E. Acree

New York State Agricultural Experiment Station, Cornell University, Geneva, New York 14456

Contract No. DAAG 17-70-C-0181

September 1973

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY TROOP SUPPORT COMMAND

FOOD LABORATORY
FL-175

AD-767 536

EVALUATION OF SULFITE TREATMENT OF RED TART CHERRIES, GREEN BELL PEPPERS, AND APPLES FOR DEHYDRATION

Robert L. LaBelle, et al

New York State Agricultural Experiment Station

Prepared for:

Army Natick Laboratories

September 1973

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
New York State Agricultural Experiment Station Cornell University Geneva, New York 14456	Unclaaaified
	2b. GROUP

3. REPORT TITLE

EVALUATION OF SULFITE TREATMENT OF RED TART CHERRIES, GREEN BELL PEPPERS, AND APPLES FOR DEHYDRATION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final June 1970 - June 1972

5. AUTHOR(S) (First name, middle initial, last name)

Robert L. LaBelle and Terry E. Acree

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1973	146 141	29

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
DAAG17-70-C-0181	
b. PROJECT NO. 728012.12	74-14-FL
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	FL-175

Details of illustrations in this document may be better studied on microfiche.

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

Red tart cherries, diced green bell peppera, and diced apple were dried in various ways with and without sulfite treatment. Drying alternatives included short exposure to circulating hot air (air-drying), intermediate exposure at reduced temperature and preaaure (vacuum-drying) and long exposure to high vacuum in the frozen state (freeze-drying). Sulfite treatment of theae materiala was accomplished by dipping in an aqueous solution of $NaHSO_3$ (1000-10,000 ppm) or by tumbling in a mixture of SO_2 (2-4%) in air. The dried products were hermetically packaged, in aome casea under nitrogen or with desiccant, and stored for six months at -35 or +100°F. Product quality was then evaluated in terms of moisture, residual SO_2, color, odor or flavor, and rehydration characteristics.

The most important consideration in keeping quality was moisture content. In-package desiccation was required to reduce two-stage, air/vacuum-dried cherries or peppers to a moisture level low enough (1-2%) that quality remained acceptable in storage at 100°F. Sulfite treatment and packing under nitrogen were insufficient separately or together, to provide the necessary protection against browning reactions at higher moisture. And only a slight improvement in quality was noted in aulfited products dried to the lower moisture, in which condition even untreated controls were usually just about accepcable. In-package desiccation was not sufficient to provide final drying for higher moisture products prepared only by air-drying and was mainly unnecessary for chose properly freeze-dried.

(See continuation sheet)

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Drying	8					
Air-Drying	8					
Vacuum-Drying	8					
Freeze-Drying	8					
Cherries	9		7		7	
Peppers	9		7		7	
Apples	9		7		7	
Dried Foods	9		7		7	
Sulfiting	10		6			
Dehydration	4					
Nitrogen			6			
Desiccants			6			
Storage					6	
Packaging					6	
Temperature					6	
Moisture					7	
Color					7	
Odor					7	
Flavor					7	
Rehydration					7	

Approved for public release;
distribution unlimited

AD_____

TECHNICAL REPORT
74-14-FL

EVALUATION OF SULFITE TREATMENT OF RED TART CHERRIES, GREEN BELL PEPPERS, AND APPLES FOR DEHYDRATION

by

Robert L. LaBelle and Terry E. Acree

New York State Agricultural Experiment Station
Cornell University
Geneva, New York 14456

Contract No. DAAG17-70-C-0181

Project reference:
728012.12

Series: FL-175

Food Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

13. Abstract (continued):

Air/vacuum-drying, preceded by SO_2 treatment for diced apple or interstage gas-sulfiting for cherries, is recommended. Diced pepper can be prepared like cherries or by freeze-drying, but with sulfiting optional and of less importance.

FOREWORD

Cherries, apples and green bell peppers are used in large quantities by military installations overseas. The use of these products is required to prepare a variety of food products for military consumption. Where these items can be shipped and stored in the dehydrated form, there would accrue desirable space, and economic savings.

However, problems were encountered relative to undesirable changes during storage at elevated temperatures. Therefore, this contract was awarded in order to determine the optimum processing conditions for the production of dehydrated products which can be restored to the predehydration characteristics upon rehydration, especially upon prolonged storage at elevated temperatures.

Mr. Robert L. LaBelle was the Principal Investigator and Dr. Terry E. Acree the Collaborator in the research work for Cornell University. The U.S. Army Natick Laboratories Project Officer was Dr. Abdul R. Rahman of Plant Products Division and The Alternate Project Officer was Mr. Glenn Schafer of Plant Products Division. The work was conducted under Project No. 728012.12, Production Engineering.

TABLE OF CONTENTS

Section No.	Section heading	Page No.
	LIST OF TABLES AND FIGURES NOT IN APPENDIX	iv
	ABSTRACT	vi
4.1	Introduction	1
	Part I - Sulfite treatments, drying methods, and storage conditions	
4.2	Experimental Procedure:	3
4.21	Preparation of fresh product	3
4.22	Sulfite treatment	4
4.23	Dehydration	6
4.24	Packaging and storage	8
4.25	Evaluation of dried products	9
4.3-4.5	Results and Discussion:	13
4.31	Results with red tart cherries in 1970	13
4.32	Sulfite residuals in cherries in 1971	13
4.33	Headspace oxygen and the role of nitrogen-pack	16
4.34	In-package desiccation	17
4.35	Color vs. moisture level	18
4.36	Effect of sulfite treatment on color preservation	18
4.37	Comparison of drying methods	24
4.41	Results with green bell peppers in 1970	27
4.42	Results with green bell pepper in 1971	28
4.51	Results with apples in 1970	30
4.52	Results with apples in 1971	35
4.6	Conclusions and Recommendations:	36
4.61	Red tart cherries	36
4.62	Green bell peppers	37
4.63	Apples	38
4.64	Summary of recommendations	39

Section No.	Section Heading	Page No.
	Part II - Sulfite Analysis	
4.7	Experimental Procedure:	40
4.71	Model SO_2 solutions	40
4.72	Preparation of extracts	40
4.73	I_2 titrations	40
4.74	Purge-colorimetric procedure	41
4.75	Statistics	44
4.8	Results and Discussion:	45
4.81	Effect of pH on I_2 titrations	45
4.82	Acetaldehyde-SO_2 solutions as a model for "free" SO_2 determinations	50
4.83	Discrepancies between the two methods using cherries and peppers	50
4.9	Conclusions and Recommendations:	56
4A	Appendix	57
4A.1	Glossary	58
4A.2	Descriptive terms for hedonic scale	59
4A.3	Complete tabulated and summarized data (see separate list of tables)	60
4A.4	Diagrams and photographs of equipment	123
4A.5	Samples of dried products provided to NLABS	131
4A.6	Disclaimer on trade names of equipment	132
4A.7	Selected bibliography	133
4A.8	Acknowledgements	135

LISTS OF TABLES AND FIGURES, OTHER THAN THOSE INCLUDED IN THE APPENDIX

TABLES:		Page
4.32.1	Relative absorption of SO_2 (ppm) by pitted cherries during pretreatment or treatment after partial drying by either dipping or gassing	14
4.32.2	Sulfite residuals (total) in red tart cherries as a function of mode (dip or gas) and level of treatment	15
4.33	Loss of headspace O_2 and cherry color related to product moisture level	16
4.34	Effect of in-package desiccation on final moisture and relative dryness of red tart cherries (1971 pack)	17
4.37.1	Comparison of drying methods - cherries, 1971	24
4.37.2	Comparison of drying methods with respect to SO_2 (total) remaining in cherries after drying and after storage 1971	26
4.51	Effect of treatment level (with NaCl or $NaHSO_3$) on rehydration characteristics of air- and freeze-dried apple pieces (1970 pack)	34

FIGURES:		
4.35.1	Relationship between cherry color rating (subjective) and per cent moisture	19
4.35.2	Relationship between cherry color (Hunter a, or redness) and per cent moisture	20
4.35.3	Relationship between cherry color (Hunter L, or brightness) and per cent moisture	21
4.36.1	Effect of the higher sulfite residuals obtained by gas treatment on cherry color (Hunter a, or redness) after six month's frozen storage	22
4.36.2	Effect of the higher sulfite residuals obtained by gas treatment on cherry color (Hunter L, or brightness) after six month's frozen storage	23
4.42	SO_2 residual after frozen storage as a function of treatment	31
4.74.1	Apparatus used to purge SO_2 from sample solutions	42
4.74.2	A standard curve for the purging procedure showing the optical density at 412 nm vs. g of SO_2 in a 10-ml sample	43

LIST OF TABLES AND FIGURES (cont.)

FIGURES (cont.):

		Page
4.81.1	A plot of the ml of .02N iodine required to titrate 180 ppm SO_2 phosphate buffer solution.	46
4.81.2	A plot of the ml of .02N iodine required to titrate a dehydrated cherry filtrate	47
4.81.3	A plot of the ml of .02N iodine required to titrate a dehydrated pepper filtrate	48
4.81.4	A plot of the ml of .02N iodine required to titrate a dehydrated apple filtrate	49
4.82.1	Shows the per cent recovery of SO_2 from a 50-ppm SO_2 solution containing acetaldehyde vs. the molar ratio of acetaldehyde to SO_2	51
4.82.2	Shows the per cent recovery of SO_2 using the colorimetric purging method vs. the per cent recovery of SO_2 using the iodine titration method. These solutions contained different ratios of acetaldehyde to SO_2	52
4.83	A plot of the amount of SO_2 added to a cherry filtrate vs the amount of SO_2 recovered using two methods of analysis	55

ABSTRACT

Red tart cherries, diced green bell peppers, and diced apple were dried in various ways with and without sulfite treatment. Drying alternatives included short exposure to circulating hot air (air-drying), intermediate exposure at reduced temperature and pressure (vacuum-drying) and long exposure to high vacuum in the frozen state (freeze-drying). Sulfite treatment of these materials was accomplished by dipping in an aqueous solution of $NaHSO_3$ (1000-10,000 ppm) or by tumbling in a mixture of SO_2 (2-4%) in air. The dried products were hermetically packaged, in some cases under nitrogen or with desiccant, and stored for six months at -35 or +100°F. Product quality was then evaluated in terms of moisture, residual SO_2, color, odor or flavor, and rehydration characteristics.

The most important consideration in keeping quality was moisture content. In-package desiccation was required to reduce two-stage, air/vacuum-dried cherries or peppers to a moisture level low enough (1-2%) that quality remained acceptable in storage at 100°F. Sulfite treatment and packing under nitrogen were insufficient, separately or together, to provide the necessary protection against browning reactions at higher moisture. And only a slight improvement in quality was noted in sulfited products dried to the lower moisture, in which condition even untreated controls were usually just about acceptable. In-package desiccation was not sufficient to provide final drying for higher moisture products prepared only by air-drying and was mainly unnecessary for those properly freeze-dried.

Air/vacuum-drying, preceded by SO_2 treatment for diced apple or interstage gas-sulfiting for cherries, is recommended. Diced pepper can be prepared like cherries or by freeze-drying, but with sulfiting optional and of less importance.

4.1 INTRODUCTION

The sulfiting and drying of fruits and vegetables might be characterized as an old art and a new science. Its practice in many commercial applications has a long history, yet when measured against military requirements and higher standards of quality, the results have left something to be desired. This is particularly true when extended storage under difficult field conditions are intended.

Preservation from microbial spoilage presents no great difficulty, although the mechanics of handling rather fragile food materials and of moisture removal from diverse textures and forms of tissues containing various soluble solids require careful attention to equipment and operation. In that respect, no two foods are alike, and their special characteristics must always be taken into account. But what has become increasingly important as food processing, and consumers, become more sophisticated is that the organoleptic qualities of the fresh product be reasonably maintained, not only through processing but during storage as well. Otherwise, the reconstituted product will little resemble the fresh product and will neither be readily accepted nor consumed, thus defeating the purpose of preservation.

It is mainly to this end that pretreatment with sulfur dioxide in some form and manner was introduced, far more for its ability to inhibit both enzymatic oxidations and various non-enzymatic browning reactions than for its ancillary anti-microbial action. But unfortunately, its use has often been excessive, resulting in corrosion of containers and equipment used to prepare the product for use, in carry-over of its own disagreeable aftertaste into the food, and even in suspected interference with nutritional value. Procedures for applying SO_2 to the fresh product accurately enough to obtain the proper amount to persist in the dried product through storage has gradually been developed and improved since the first flush of scientific development during World War II. The emphasis most recently, especially in the face of greater controls over food additives, has been in using just enough SO_2 to accomplish the desired preservative effect. And this has necessarily required that an accurate analysis of the content and chemical state of the SO_2 can be made. It is to these two requirements that the present study is devoted.

An added feature of this work, and one which in retrospect has loomed quite large, is an attempt to deal with one of the most difficult food materials, from the standpoints of the mechanics of sulfiting and drying, and of storage stability - the red tart (or pie) cherry. This is not only a most fragile

tissue wrapped in a relatively impervious skin, becoming even more liable to physical damage as well as wet and sticky when pitted, but has a delightful but very unstable red color. And in the Montmorency variety most commonly processed, the amount of anthocyanin pigment, contained only in a thin layer in the skin, is very small, so that losses during processing and storage are quickly apparent. Dehydrofreezing has only in the last decade been adapted to this difficult product at this laboratory, though not yet adopted commercially. But with this background it was thought possible to demonstrate some improvements in dehydration methods for the red tart cherry, never satisfactory in the past.

PART I - SULFITE TREATMENTS, DRYING METHODS, AND STORAGE CONDITIONS

4.2 EXPERIMENTAL PROCEDURE

In the procedures described here the well-developed pilot plant facilities of the Department of Food Science and Technology were utilized to prepare, sulfite, and dehydrate the food materials under study. While the size of the experimental lots was not large, ranging from 2 to 20 kg. the equipment and techniques employed were sufficiently typical of commercial methods to permit reasonable seale-up. In several instanees where some doubt exists on this point, attention is called to the possible diserepancy.

4.21 Preparation of the Fresh Produet -

a) Red tart cherries (var. Montmorency) werc harvcsted by laboratory pcrsonnel at a neighboring commercial orchard usually late in the afternoon. Aftcr a preliminary wash the fruit was chilled in ice water and soaked overnight at 35°F to permit normal firming without saerifice of red color. The following morning the fruit was drained, divided into the desired lot size, and storcd in cold air until used later the same day. The firmed cherries were sorted for defccts, pitted in a laboratory-size pitter (Dunkley), and drained of free juice before sulfite treatment or drying.

b) Green bell peppers (var. Calwonder - 1970 and Staddon Select - 1971) were purehased ready harvested from eommercial growers and stored for up to a month at 35°F until used. Peppers having red blush were either sorted out or, when supply was short, trimmed of the eolored portion. A diced fresh product was prepared by cutting the peppers in half by hand, trimming away seeds and excess pale-colored partition tissue, and then cutting in a dicing machine (Ursehel Model G) to the desired 3/8" size pieees.

c) Apples (var. Monroe or Mutsu) were harvested from the Experiment Station orchards and held at 35°F and 85-90% humidity until used. Since most of the dried apple produets were processed late in the season (March - May) because of the press of other work, this fruit was quite ripe, having a bland flavor, tender texture, and inereased permeability to SO_2. The apples were peeled and cored on standard four-head machines (Pease) and trimmed by hand as required. Oversize coring knives were not ordinarily used, resulting in the appearanee of some earpel tissue in the final product. The peeled, cored, and trimmed fruit was then promptly eut in the Urschel dieer to 3/8" diecs.

4.22 Sulfite Treatment - The absorption of SO_2 on or into the food pieces was accomplished by contacting them with an aqueous solution of SO_2 or of $NaHSO_3$, or with a dilute mixture of SO_2 gas in air. Dipping the pieces briefly in a sulfite bath has been commonly used as an antioxidant pretreatment for freezing, dehydrofreezing, or dehydration because of the ease of controlling the solution concentration. On the other hand, sulfuring fruit preliminary to drying has usually meant subjecting the pieces to the fumes of burning sulfur over a relatively long period of several hours with excessive pick-up of SO_2.

One of two methods was used to insure good contact between fresh solution and the individual pieces. The pieces were enclosed in a stainless steel wire-mesh basket complete with lid to keep the pieces from floating out when immersed. Moving the basket continuously up and down in the solution during the desired treatment time renewed the solution at the piece surfaces and ensured good absorption of SO_2 by maintaining the maximal driving force or concentration gradient. Another method used was to dump the pieces into the solution and gently mix with a paddle to provide for good contact with fresh solution and immersion of all pieces (since diced pepper and apple both float). In this case, abrupt termination of the treatment for all pieces alike is accomplished by dumping the mixture of pieces and sulfite solution through a wire-mesh screen or basket (or the dryer tray itself) and catching the used solution in another container for testing or reuse. Ordinarily, three volumes of solution (3x the weight of the pieces to be sulfited) was used to ensure good contact and to provide a suitable reservoir of sulfite ions.

The strength of the solution may be depleted by as much as 10% during a single use because of the ready absorption of the SO_2. Its strength was measured both before and after by titrating an aliquot with standardized (0.1N) iodine solution and expressed as the mean of the two determinations. Both sulfite bath and piece temperatures were maintained near 70°F - high enough to give ready absorption and low enough to prevent excessive fuming. Solutions were not ordinarily reused except for the second mid-drying treatment of the same lot.

Treatment of the food pieces with a gaseous mixture of SO_2 in air was carried out by procedures previously developed in this laboratory for apples. The pieces were contacted with the SO_2 mixture in a vacuum tumble dryer (The Patterson-Kelly Co., Inc., Model VD-1-B) operated at 4 rpm to provide some but not excessive mixing action that might cause abrasion of the apple tissue or tearing of the pitted cherries. A

constant and copious metered flow of SO_2 and air was maintained through the chamber during treatment. It was necessary to meter in more SO_2 than desired as the effective treatment level because of the rapid absorption of SO_2 on the wet food pieces. In addition, the chamber was precharged with a higher level of SO_2 than desired before loading. The actual effective level was monitored by continuously sampling the outflow from the chamber with a recording SO_2 analyzer (Leeds & Northrup Model 7802-D-A2). This equipment is shown in Fig. 4A.4.1. The sulfited pieces were discharged directly onto the dryer tray, after a short period (2 min) of flushing out the chamber with air alone. Because of this gradual decrease in treatment level of SO_2 at the end of the treatment and the difficulty in obtaining the desired level of SO_2 initially because of rapid absorption, the treatment level could not be maintained constant; the actual effective level was taken as the average calculated from the recorded data as monitored by the SO_2 analyzer. Treatment temperature was maintained at 80°F by a flow of warm water through the jacket of the tumble dryer, although initial piece temperature tended to be lower than this because of evaporative cooling. The effective temperature was probably closer to 70°F, as in the dip treatments.

Dipping treatment levels were varied between none (sometimes effected as a dip in plain water) and 10,000 ppm SO_2 (see tables in Appendix). $NaHSO_3$ was ordinarily used as the source of sulfite ion, as this gave a relatively non-fuming solution that is more comfortable for the personnel to work with. However, some lots were treated with an aqueous solution of SO_2, sometimes referred to as H_2SO_3, or sulfurous acid. Treatment levels with gaseous SO_2 ranged up to 4%, this being the highest that could be monitored successfully with the 0-5% range of the SO_2 analyzer. In order to keep experimental variables within manageable limits, the temperature and duration of treatment were not varied. The only exception to this was that the standard times for treatment with gaseous SO_2 were chosen as inversely proportional to concentration according to the following schedule:

% SO_2 in air	treatment duration, min. (less flushing
1	10
2	5
4	2-1/2

The standard duration of dipping treatments was 2 min.

4.23 Dehydration - The removal of moisture from the products sufficient for preservation was accomplished in three different dryers, or in combinations thereof. A recirculation cabinet dryer was used to contact the products with flowing hot air, and this is referred to as air-drying (code: AD). A vacuum shelf dryer permitted the product to be heated in a moderate (4 mm Hg) vacuum for the relatively slow removal of moisture to lower levels, at lower product temperature, and with somewhat less shrinking. A medium size freeze-dryer equipped with a mechanical vacuum pump permitted food to be dried at high vacuum (<100 nm, or .1 mm Hg) from the frozen state so that the product pieces would retain their original shape without shrinking and be dried at even lower average temperature.

a) The recirculation cabinet dryer was of custom design with a chamber measuring 40" x 30" x 38" in which air could be circulated through one or two banks of 18" x 30" trays having 1/16" perforated stainless bottoms or across as many as 36 12" x 30" trays having 1/8" stainless mesh surfaces. Air heated by contact with steam coils was circulated by a large variable-speed blower and precisely regulated by automatic temperature and humidity controllers. Drying was periodically interrupted to remove the trays briefly for weighing and reorientation in the drying chamber. In some cases the product was also mixed and redistributed to permit more uniform drying and prevent excessive sticking to the trays. (See Fig. 4A.4.2).

In order to prevent product temperature from rising so high during drying that color and flavor might be adversely affected, air temperature was programmed downward as drying progressed. In effect, the product is initially near the wet-bulb temperature but finally approaches that of the dry-bulb. The programmed stepwise decrease in drying temperature used for slow-drying red tart cherries was as follows:

	Drying time, min.				
	0 - 15	15 - 35	35 - 60	60 - 90	90+
Dry-bulb temp. (t_d), °F	225	210	190	170	150
Wet-bulb temp. (t_w), °F	125	115	100	90	82

Under this regime cherry temperature remained in the range 140 - 160°F with little apparent thermal damage. On the other hand, pepper and apple dices dried so much more rapidly that much lower drying temperatures were necessary in order to control the weight reduction. In the 1971 season all of the peppers were dried at dry- and wet-bulb temperatures of 165 and 90°F.

b) The vacuum shelf dryer (Blaw-Knox Model BB-4) had four 24" x 24" shelves heated by circulating hot water and was connected to the main pilot-plant vacuum system comprised of a triple steam jet capable of 4 mm Hg. The product was distributed on 24" x 12" dryer trays having either solid or 1/4" perforated stainless bottoms and placed in the chamber so as to have a heated shelf both above and below - a total of 12 sq. ft. of surface. Because the tray bottoms could not be maintained uniformily in contact with the shelves, all were raised 1/4" above the shelves on wooden dowels to prevent hot spots and non-uniform drying. The lower rate of heat transfer that resulted caused slower drying, but this could be partially overcome by higher shelf temperature. The temperatures of several typical food pieces were monitored by welded copper-Constantan thermocouples carefully inserted so as to be surrounded by the tissue. Pull-down to the final vacuum was controlled by initially bleeding in air to help sweep out the early flush of moisture and to prevent bubbling or boiling liquid out of the product that would aggravate sticking to the tray surface. However, this was no problem when the vacuum-dryer was being used on product previously dried in a first stage in the air-dryer. But it did prove to be a problem that could not be practically overcome with fresh cherries, limiting vacuum-drying (Code: VD) in this product to a second-stage operation on already partly-dried product only. (See Fig. 4A.4.3).

c) The freeze-dryer (Stokes Model 2004L3) had three 24" x 36" shelves heated by circulating warm water. The product, previously hard-frozen on 12" x 36" stainless trays at -35°F, was transferred without delay to the thoroughly predried chamber, and maximal vacuum was promptly impressed to maintain the product in a frozen state. Drying times varied from 12-16 hr. for diced pepper up to 64 hr for pitted cherries, during which the vacuum chamber pressure fell gradually from 300-400 to <100 mm Hg and the shelf temperature rose from 28°C to 35°C. The relatively small capacity of this unit and competition from other uses limited the amount of freeze-dried (Code: FD) material that could be prepared for this study, especially from fresh cherries during the short season. (See Fig. 4A.4.4).

d) Difficulties with boiling of fresh cherries in the vacuum dryer and the limited capacity of this equipment at drying times of 1-16 hr prompted us to attempt two-stage drying in which a large part of the moisture was first removed in the air-dryer. The greatest freedom from sticking problems in either dryer and the prevention of excessive oxidation of color and flavor as well as excessive shrinkage of the product led us to adopt a standard weight reduction of about 65% in the

air dryer before transfer to the vacuum-dryer. This procedure was termed air/vacuum drying (Code: AV).

e) These same considerations led us to some brief tests on air/freeze drying with peppers, limited by available time and material and by difficulty in controlling shrinkage with any reasonable proportion of air-drying.

4.24 Packaging and Storage - Equally important as processing conditions to the stability of product quality are the micro-environment within the package and the macro-environment in which the package is stored. There is opportunity within a hermetically sealed package to exclude air, or oxygen, and to retain any added antioxidants. At the same time the low moisture attained during drying can be maintained and even decreased further in activity. The exterior environment can be controlled principally from the standpoint of temperature.

The #2 (307 x 409) can was selected for packaging to provide ready hermetic sealing as well as physical protection for the rather fragile pieces of dried food. Each freshly-dried lot was transferred without delay from the dryers to a tightly closed polyethylene bag in a friction-top fruit can and allowed to equilibrate at 35°F. In order to simplify packaging technique and storage schedules, all lots were retained at 35°F until the end of the season or period of experimentation, packaged within a few days time, and placed in storage on the same day.

Samples to be stored under nitrogen were filled into #2 cans and promptly placed in a glove box (LABCONCO) in which the partial pressure of oxygen had been reduced to 5-10 mm Hg (about 1%) by prior flushing. To accomplish this initial flushing of the glove box most economically and quickly, two large (24" diam.) balloons were first inflated with nitrogen within them. Then, the residual volume of the chamber was flushed by passing in nitrogen at one side and discharging excess air and nitrogen on the other. This discharge bathed the sensing element of a small oxygen analyzer (Beckman Model 777) in order to monitor the progress of the flushing. When the oxygen level was reduced to 1% in the discharge (after about 30 min), the flow was stopped, the chamber sealed, and the balloons deflated, further reducing the oxygen level in the chamber by dilution. (See Fig. 4A.4.5).

After the open cans had remained in the nitrogen atmosphere for several hours to equilibrate, they were ready for sealing. Just prior to closing the cans, they were flushed briefly with nitrogen by inserting a thin tube down to the bottom of the

can. A portable double-seamer (Automatic Canning Devices, Inc. Model CY-1), enclosed in the glove box with the filled cans, was used to close them with a hermetically sealed lid.

Drying of the product to very low levels (<1% moisture) was accomplished in some storage samples by in-package desiccation. Packets containing 20 g of calcined lime (CaO) in a permeable, heat-sealable paper (Multiform Desiccant Products, Inc.) were placed in the can just before filling.

One or more packages, depending on product bulk density, were placed in the two storages of most interest; at -35°F to serve as controls and at 100°F - the usual military test temperature for stored foods. A more straightforward control sample might have been provided by analyzing the products completely before storage. But since this was inconvenient in the press of other seasonal work, and since it was assumed that changes in the product held at -35°F would be negligible, the control samples were analyzed after six month's storage along with those under test. This also had the advantage of permitting the controls and test samples to be evaluated organoleptically side by side.

The several packaging and storage combinations used in this study may be summarized as follows, along with the code letter used to designate each more simply:

Packaged:	Without desiccant		With desiccant	
	in air	in N_2	in air	in N_2
Stored @ -35°F	-	A	-	AA
Stored @ 100°F	B	C	-	D

4.25 Evaluation of Dried Products - The final test of the processing, packaging, and storing procedures used is, of course, in the quality of the dried product. The laboratory tests used in determining both their useful qualities and how much moisture, O_2, and SO_2 actually remained to affect the product are discussed in this section.

a) Bulk density is an important consideration in military transport and storage. The greater the bulk density, the more efficiently these services may be performed. Of the two measures of bulk density - loose-pack and close-pack (1), the latter is of most interest, since it can be determined more precisely and, when the effort is made to achieve it, results

1) LaBelle, R. L. 1964. Bulk density - a versatile measure of food texture and bulk. Food Technol. 18:6, 89-94.

in more compact and efficient packaging. To measure it, a rigid container of known volume is progressively filled by pouring from another while gently tapping it on a firm surface. The container should be of sufficient size that its diameter is at least 8X that of the particulate product, such as cherries or diced peppers, to avoid edge effect. The container is filled level full either by striking with zig-zag strokes of a straight edge across the upper edge, or, in the case of materials such as these in which one unit does not readily slip over another, by distributing material evenly over the top surface so that no piece sticks up more than half its diameter. The filled container is given a few final taps to insure that settling is complete. The measurement should be repeated two or three times with the same or different material, depending on supply. The bulk density is calculated as mean net weight divided by the volume.

b) Determination of the SO_2 content of dip solutions used and residual SO_2 found in the sulfited product before and after storage is presented in section 4.5.3.

c) Oxygen in the headspace of the #2 can of dried product was determined after storage only. The O_2 analyzer was not available when the cans were filled, and we assumed that the initial level was the same as or lower than that indicated for the glove box in which they were closed. The test can was punctured in the rigid container headspace sampler (Precision Equipment Co.) after evacuation of the system consisting of sampler, measuring cell of the oxygen analyzer (Beckman Model E2), and two manometers. Gas from the can (interstitial rather than headspace in these particulate dried products) expanded into the cell where the partial pressure of O_2 was determined by relative magnetic permeability and into the manometer where the final pressure of the expanded sample was read. This pressure was used to correct the apparent O_2 content back to the approximately atmospheric pressure that prevailed in the can.

d) Moisture was determined by blending a 40-g sample of the dried product with 200 g of water and drying for 48 hr. in a vacuum oven at 65°C to constant weight.

e) Reflected color of the products was measured with the Hunter Color and Color Difference Meter Model D25 using the following standards for the three products involved:

	L	a	b
cherries	26.1	26.2	12.3
peppers	51.6	- 3.5	30.6
apples	85.3	- 5.4	22.4

f) The color, flavor or odor, and relative dryness of dried samples after storage was judged by the principal investigator in consultation with one or more assistants soon after the cans were opened. Samples from each packaging and storage condition and from related sulfite and drying treatments were judged side-by side in each sitting. Color was judged under a large daylight lamp (Macbeth Model 4C). A hedonic scale of 1-10 was used to rate each factor, according to the descriptive terms shown in Section 4A.2 of the Appendix.

g) Rehydration was carried out on samples sufficiently large to provide the required amount for texture tests. Procedures used were similar to those worked out in this laboratory after long experience (2). To a weighed amount of dried material, in a graduated beaker, a proportional quantity of near-boiling water was added. A nesting beaker was superimposed to keep the often-bouyant dried food completely immersed, and the rehydrating sample was set aside to cool in ambient air. After a predetermined period the bulk volume of the redhydrated sample was measured by replacing the superimposed beaker with a perforated metal piston of known weight and noting the volume of the food material (to $\pm$ 5 ml) slightly compressed against the bottom of the beaker under load (1.6 - 2.1 g/cm^2) after 60 sec.

The sample was then drained on an 8-mesh screen tilted at 25° for 2 min to establish the drained weight. Since the product had cooled back to room temperature during the rehydration period, there was no problem with evaporation loss during the measurement, or low readings due to excessive draining of warm, low-viscosity liquid. Since rehydration ratio is meaningless or misleading without reference to the degree of dehydration, the results are expressed as % Recovery based on the weight of material entering the dryer and taking into account the weight reduction during drying. This is calculated as:

$$\% \text{ Recovery} = (1 - \% \text{ W.R.}/100)\ (\text{Drained Wt.}/\text{sample wt.})$$

(2) LaBelle, R. L. 1966. Proceedings of the Symposium, "Frontiers in Food Research", Cornell University. Ithaca, N. Y. pp. 109-114.

The following parameters were used in rehydrating various types of dried products:

	Dried sample wt., g	Hot water added, g	Rehydration period, hr.
Cherries:			
air-dried	100	450	16
air/vacuum dried	75	400	4
freeze-dried	50	350	1-1/2
Apples:			
air-dried	20	200	2
freeze-dried	20	200	1

h) The texture of the rehydrated material was measured as the resistance to compression and extrusion in a special cell on an universal testing machine (Instron Model TTCM). A 150- to 200-g sample of freshly-drained material at 75°F was placed in a 10-cm diameter cylinder and compressed with a piston advancing at 10-20 cm/min and having both annular and axial clearances of 4 mm. Texture was expressed as the mean maximal force exerted, or the resistance to, compression and back-extrusion through the annual clearance, as determined by planimetry from the recorded trace.

4.3 RESULTS AND DISCUSSION

4.31 Results with Red Tart Cherries in 1970 - As was pointed out in the second progress report, the results obtained from the experiments on cherry sulfiting and dehydration in 1970 were largely negative. None of the samples held at 100°F, nor even at 75°F, sufficiently retained fresh color and flavor to be satisfactory, but oxidized rather badly. This was attributed first to the failure to attain moistures lower than 4% and second to negligibly low sulfite residuals (See Table 2.2). To overcome these deficiencies it was decided to turn, in the following season, to in-package desiccation and to sulfite treatments applied after partial drying to diminish the loss of absorbed SO_2 during drying. Since the control samples held at -35°F, and therefore representing the "as-freshly-dried" condition, were of good quality, it was assumed that protection was particularly needed during storage, rather than during drying.

4.32 Sulfite Residuals in Cherries in 1971 - It should be pointed out that the sulfite concentrations in the dipping solutions turned out to be substantially below nominal, in part because of a failure to take into account the moisture in the $NaHSO_3$ crystals used. However, in every case the actual concentration was determined before and after dip, and the desired relative treatments were obtained, even though not at the arbitrarily chosen levels.

Judging from the SO_2 residuals determined just after treatment and before any loss due to drying, absorption of SO_2 by the fresh cherries was greater by dipping treatment than by exposure to SO_2 gas, while just the opposite was true of sulfite treatment after partial drying. This is particularly fortunate and useful in that fresh pitted cherries are messy to treat by gassing in otherwise dry equipment. While this is to some extent true of partly dried cherries as well, it is a step backward to rewet them by dipping. The surprisingly large differences in absorption by these two modes of treatment, perhaps depending on moisture in the product, is shown in Table 4.32.1 following:

TABLE 4.32.1 RELATIVE ABSORPTION OF SO_2 (ppm) BY PITTED CHERRIES DURING PRETREATMENT OR TREATMENT AFTER PARTIAL DRYING, BY EITHER DIPPING OR GASSING

		Sulfite dip @ 4,000 ppm		Treatment with 4% SO_2 in air
Pretreatment	(5)	186	(4)	24
Treatment after partial drying	(8)	68	(11)	238

(The figures in parentheses are the number of lots from which data were taken)

The extent to which absorption and retention of SO_2 followed the concentrations used in the treatments is shown in Table 4.32.2. The relation between the actual treatment concentrations and the residuals (total SO_2) found in the fruit both directly after treatment and after drying (or further drying) are shown for air-dried and air/vacuum-dried cherries. While there was an expected tendency for diminishing returns in SO_2 absorption as treatment level increased, the residuals after drying, which is the more important aspect, were more than proportionately increased. This demonstrates the importance of employing sufficiently strong treatment levels, lest it be largely lost during drying.

It is particularly significant that treatment with 2% SO_2 gas after partial drying was just as effective whether pretreatment at 4% was carried out or not (204 vs. 205 ppm). This was not true of dipping the fruit in aqueous sulfite solutions where treatment after partial drying alone provided only slightly more than half the residual in the dried product (26 vs. 43 ppm) as when pretreatment at about the same level was also effected. The greater absorption is evident right after the second treatment (97 vs. 23 ppm).

TABLE 4.32.2 SULFITE RESIDUALS (TOTAL) IN RED TART CHERRIES AS A FUNCTION OF MODE (dip or gas) AND LEVEL OF TREATMENT

SO_2 conc'n. in dip, ppm.		No. of	SO_2 residual in fruit, ppm.	
Nominal	Actual	lots	Before drying	After drying
I) Dipping treatment before drying:				
2,000	1,760	1	95	9
4,000	3,300	2	185	26
	3,260[a]	3		43
10,000	8,320	2	333	99
II) Dipping treatment after partial drying:				
2,000	1,950	1	2	5
4,000	2,830	4	23	16
	2,850	3[a]	97	-
7,000	6,080	3	70	32
10,000	10,260	1	113	84
III) Treatment with SO_2 gas:				
Pretreatment @ 4%	(3.7%)[b]	4	24	
Pretreatment @ 4% +mid-drying treatment @ 2%	(1.8%)	4	205	112
Mid-drying treatment only:				
@ 2%	(1.7%)[b]	4	204	122
@ 3%	(2.8%)	2	278	166
@ 4%	(3.6%)	3	355	174

a) Both pretreatment + treatment at mid-drying
b) Actual % SO_2 in treatments

4.33 Headspace Oxygen and the Role of Nitrogen-pack - The relatively low levels (1%) of O_2 obtained during packaging were retained and even reduced during storage of dried cherries in hermetically-sealed cans (See Table 4A.3.18). Two observations seem particularly significant to our results. In the first place, even at low O_2 levels a considerable amount of browning and off-flavor development occurred in samples held at 100°F. Either the relatively large amount of gas contained within the interstitial spaces of the dried product in these cans contained sufficient O_2 even at the 1% level to cause oxidative damage, or the observed deterioration is only in part caused by oxidation. The second point is that when larger amounts of O_2 are present, as in the samples ("D") not flushed with N_2, the amount of O_2 that disappears during storage is proportional to the moisture level and is reflected in the degree of product color loss, as shown in Table 4.33 following.

TABLE 4.33 LOSS OF HEADSPACE O_2 AND CHERRY COLOR RELATED TO PRODUCT MOISTURE LEVEL[a]

	Moisture, %	Headspace O_2, %	Redness (Hunter a)	Brightness, (Hunter L)	Color Rating
AD	16.2	7.7	-1.6	15.0	1.3
AV	3.9	17.5	7.4	19.5	5.6
FD	2.4	19.4	11.5	22.2	6.4

a) "D" samples only.

Considerable importance has been attached to packaging these dried products under N_2 (reduced O_2 level) to afford some protection from oxidation during high temperature or prolonged storage. Comparison of the "C" and "D" packs, both of them including in-package desiccation and hence relatively low moisture levels, provides some information on this point in the present instance. But the data (Table 4A.3.34) show, paradoxically, a slight tendency for better product color in the freeze-dried "D" samples packed without N_2 flushing. This is apparently true despite higher moistures occuring in these "D" samples on the average. There is no difference in color between "C" and "D" packs of air-dried or air/vacuum-dried cherries. Apparently, this degree of N_2 flushing is not effective in controlling color loss in dried cherries within this considerable range of moisture levels (1-16%) and at 100°F storage temperature.

4.34 In-Package Desiccation - Inclusion of a 20-g packet of CaO as a desiccant in the "C" and "D" packs of cherries lowered the moisture level by an average of 2.5%, slightly more in the higher moisture products (AD and AV) and slightly less in driest (FD), as shown in Table 4.34.

TABLE 4.34 EFFECT OF IN-PACKAGE DESICCATION ON FINAL MOISTURE AND RELATIVE DRYNESS OF RED TART CHERRIES (1971 pack)

	Mode of drying	Without desiccant			With desiccant		
		A	B	av.	C	D	av
Moisture, %	AD	17.67	20.03	18.85	16.44	16.15	16.30
	AV	6.02	7.41	6.72	3.81	3.94	3.88
	FD	3.69	4.61	4.15	1.36	2.40	1.88
Relative dryness:	AD	5.6	3.2	4.4	5.9	5.8	5.8
	AV	8.3	5.7	7.0	9.5	9.6	9.5
	FD	9.2	7.6	8.4	9.6	9.7	9.6

This reduction in product moisture makes no important difference to the air-dried cherries as they are still far too wet to store well. But it dropped the moisture level of the air/vacuum-dried product by almost half (6.7 to 3.9%) to a level just short of that (3%) generally considered adequate. The moisture in the freeze-dried cherries was reduced by more than half to less than 2%, which is very good for this difficult-to-dry product. The differences in moisture level among the three different dried products and between those packaged with and without desiccant were fairly accurately judged as relative dryness (or crispness of texture), except at the high end of the scale (9-10) where products at 4% moisture or less are nearly completely crisp.

The higher moistures observed in cherries packed without desiccant and stored at 100°F ("B") in comparison with the control samples ("A") stored at -35°F may be due to the formation of water in reactions involving oxidation of carbohydrates. Increases in moisture of 2.3, 1.4, and 1.0% occurred in the three types of dried products under these storage conditions, diminishing in proportion to their initial moisture levels. However, the differences between the "C" and "D" samples both including desiccant but packed with or without N_2, were small and probably not significant.

4.35 Color vs. Moisture Level - In Figs. 4.35.1-3 the relationships between cherry color, after storage under N_2 at 100°F for six months, and final moisture level (after desiccation) is shown for air-dried and air/vacuum-dried products. Data for the freeze-dried products are included only in the graph of subjective color rating, where ratings are all relative within the product type. But the freeze-dried lots are omitted from the plots of Hunter a and L readings where their unshrunken form dilutes their redness in relation to the shrivelled cherries from air- and air/vacuum-dried products. While the "D" samples are omitted to simplify the graphs, they are very much like the "C" samples, falling in the same area of the plot.

Color ratings of 7 or greater were scored only by those products with moisture content of 3% or under, and 7 is considered here the minimal acceptable rating. But the probability of obtaining an acceptable product even at moistures less than 1% is not good, as two-thirds of these scored less than 7 - the whole group of 15 lots averaging only about 6. Most AV and FD lots packed with desiccant scored in the rage 5 - 7, which is not good enough. So, as far as storage at 100°F goes, the results seem to be - as in the 1970 season - largely negative. We have packed very few dried cherries which will meet this rigorous storage requirement.

Objective color measurements tell much the same story. Redness (Hunter a) increases sharply as moisture level is reduced below 10%. Most AV lots were below 10% moisture and most AD lots above. The reddest of the air/vacuum-dried cherries, corresponding to color rating of 6-7, had a readings above 10. The L readings were somewhat more scattered, with those corresponding to the best-colored cherries above 19.

4.36 Effect of Sulfite Treatment on Color Preservation - Inspection of color data, both objective and subjective, reveals very spotty evidence that sulfite treatment provides protection and improvement during storage. Unfortunately, the levels of SO_2 remaining in the samples stored at 100°F had diminished almost to zero, with little significance remaining. The only consistent improvement, and the greatest residuals, is found in lots treated with gaseous SO_2 and stored at -35°F among both AD and AV lots. Each of these groups of points in Figs. 4.36.1 & 2 shows an increase in both a and L readings for sulfite residuals (total) after six-month's storage in the range of 75-300 ppm. However, it is not clear whether this protection was most effective during frozen storage (when we have assumed that it is not necessary) or during drying. The analytical schedule used does not permit this differentiation.

FIG. 4.35.1 RELATIONSHIP BETWEEN CHERRY COLOR RATING (SUBJECTIVE) AND PER CENT MOISTURE.

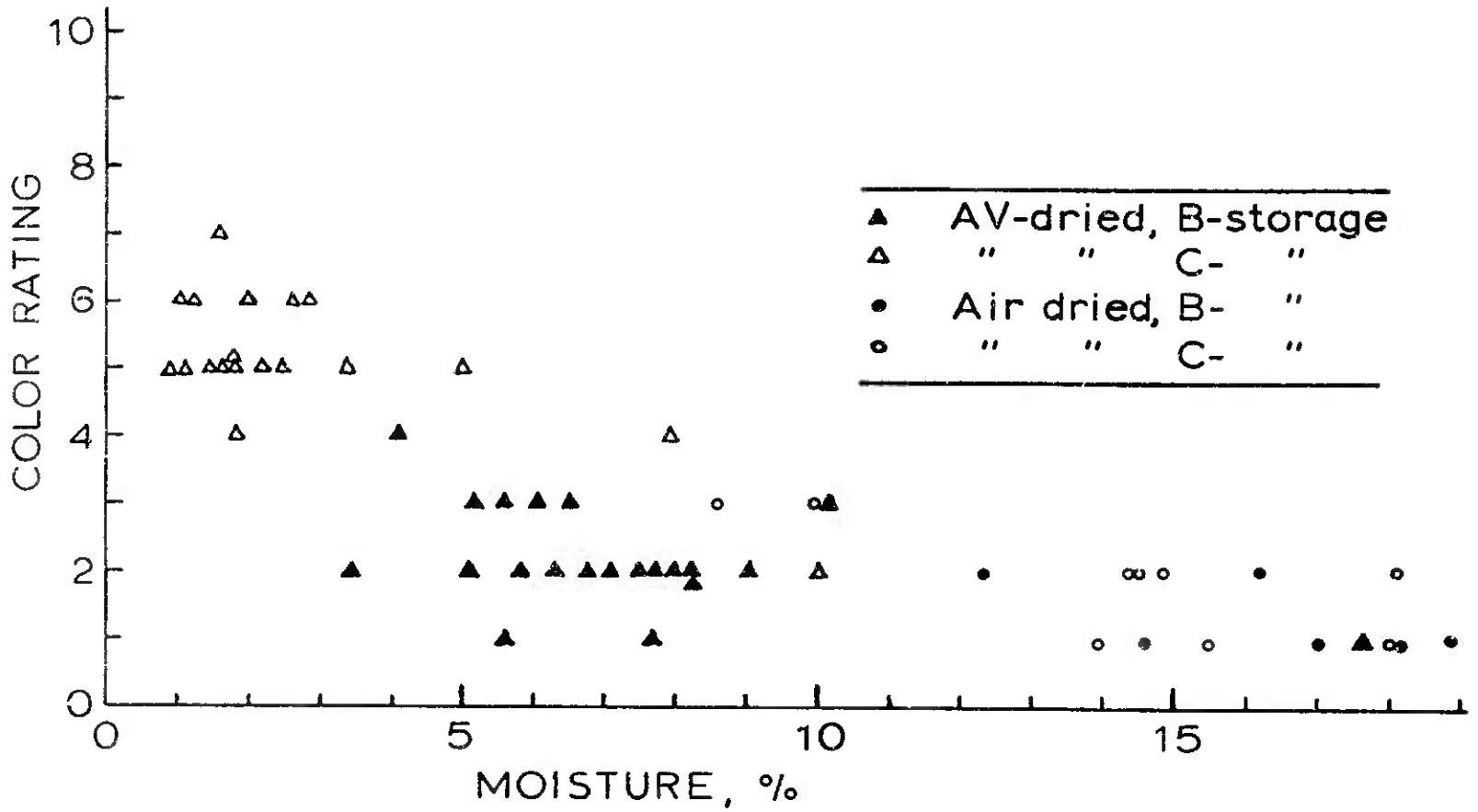


FIG. 4.35.2 RELATIONSHIP BETWEEN CHERRY COLOR (Hunter a, or redness) AND PER CENT MOISTURE.

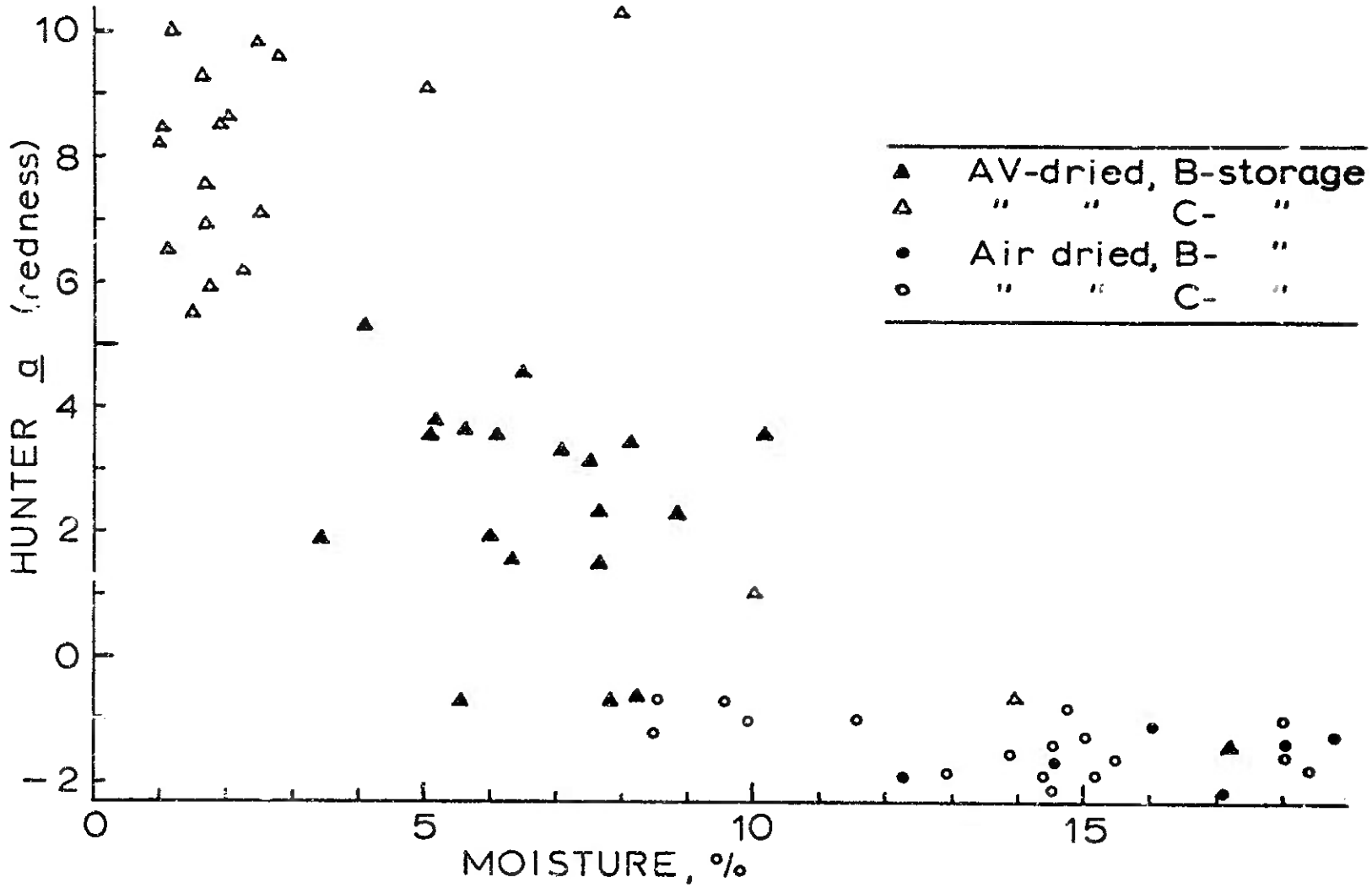


FIG. 4.35.3 RELATIONSHIP BETWEEN CHERRY COLOR (Hunter L, or brightness) AND PER CENT MOISTURE.

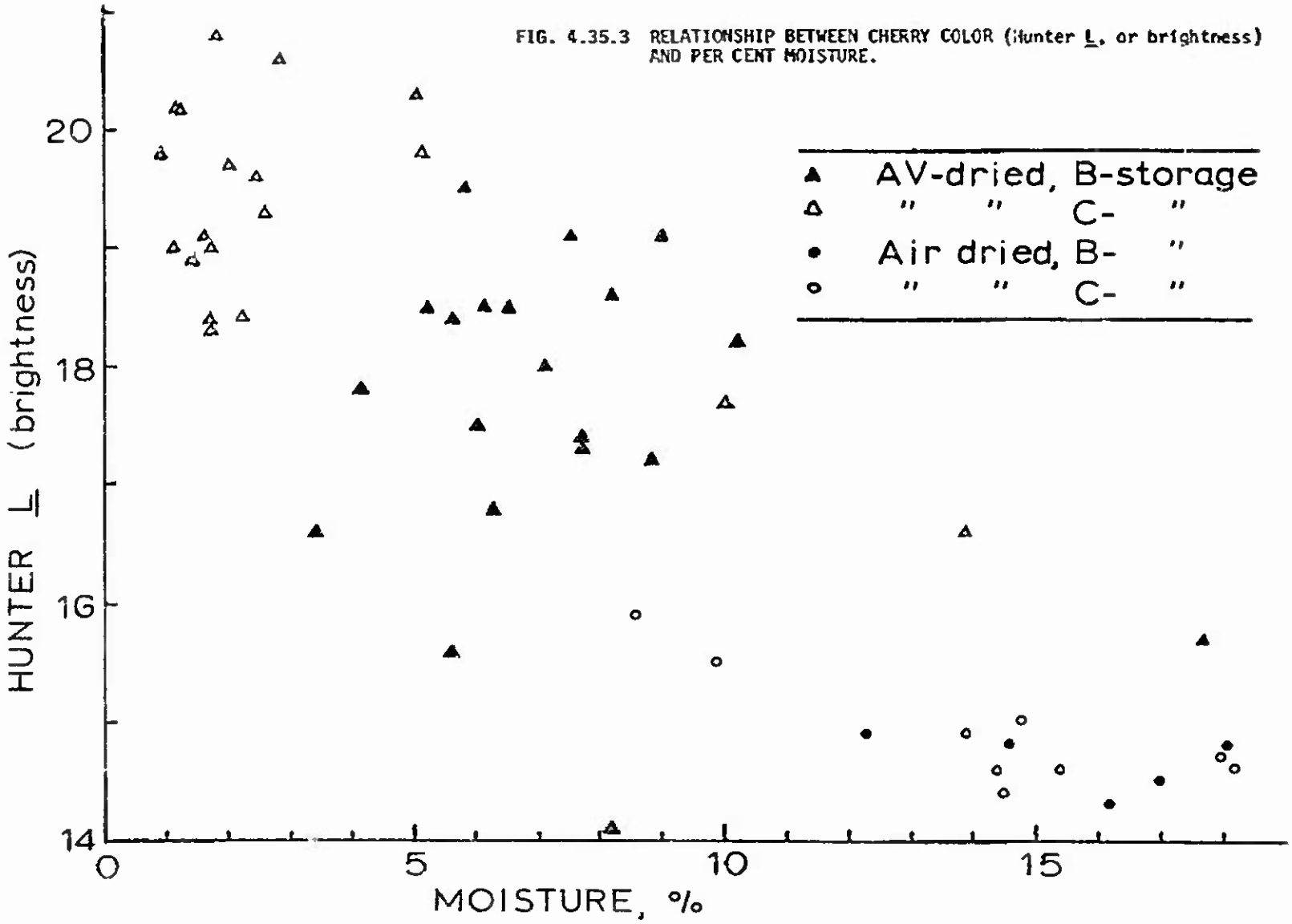


FIG. 4.36.1 EFFECT OF THE HIGHER SULFITE RESIDUALS OBTAINED BY GAS TREATMENT ON CHERRY COLOR (Hunter a, or redness) AFTER SIX MONTH'S FROZEN STORAGE.

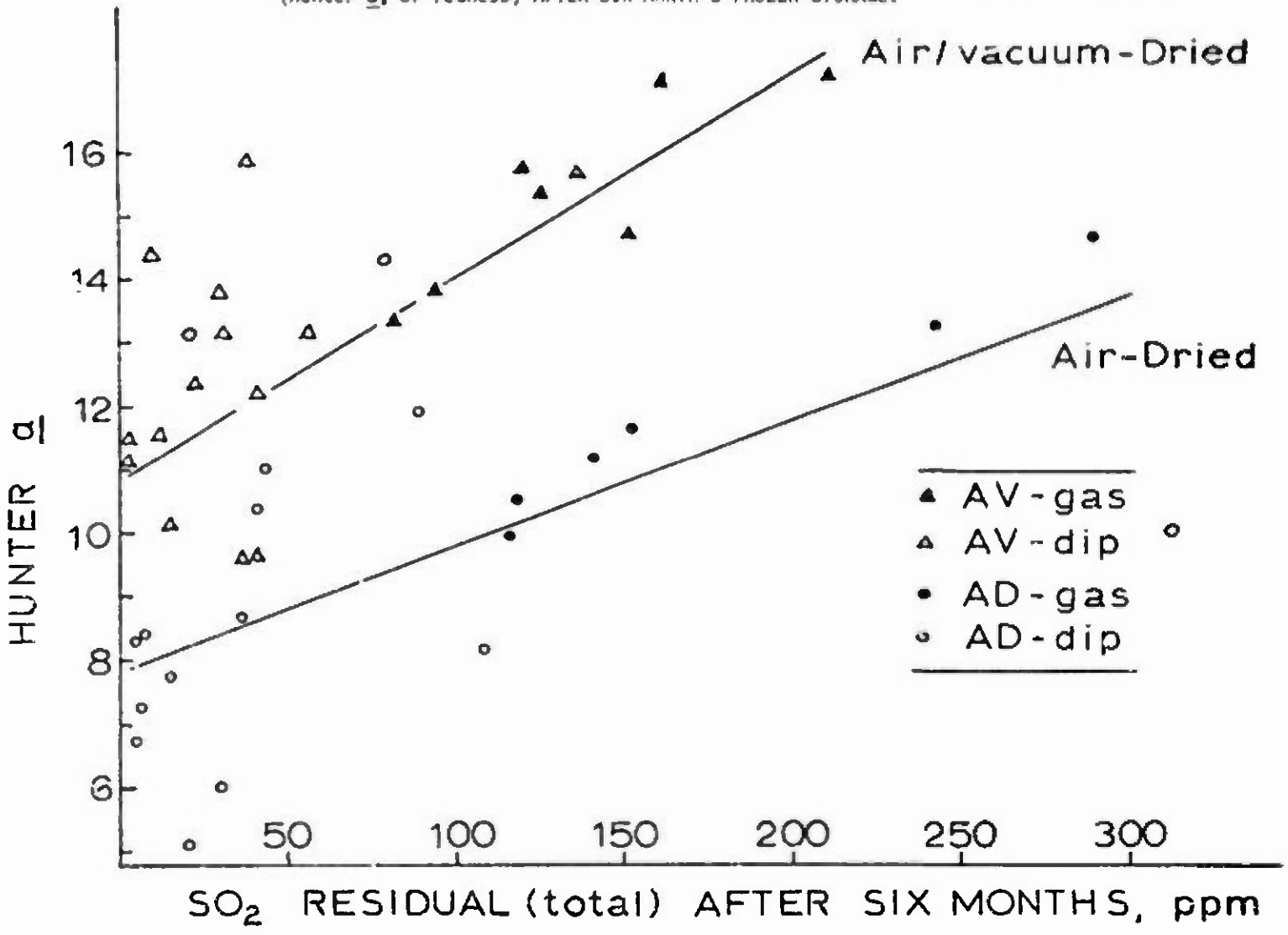
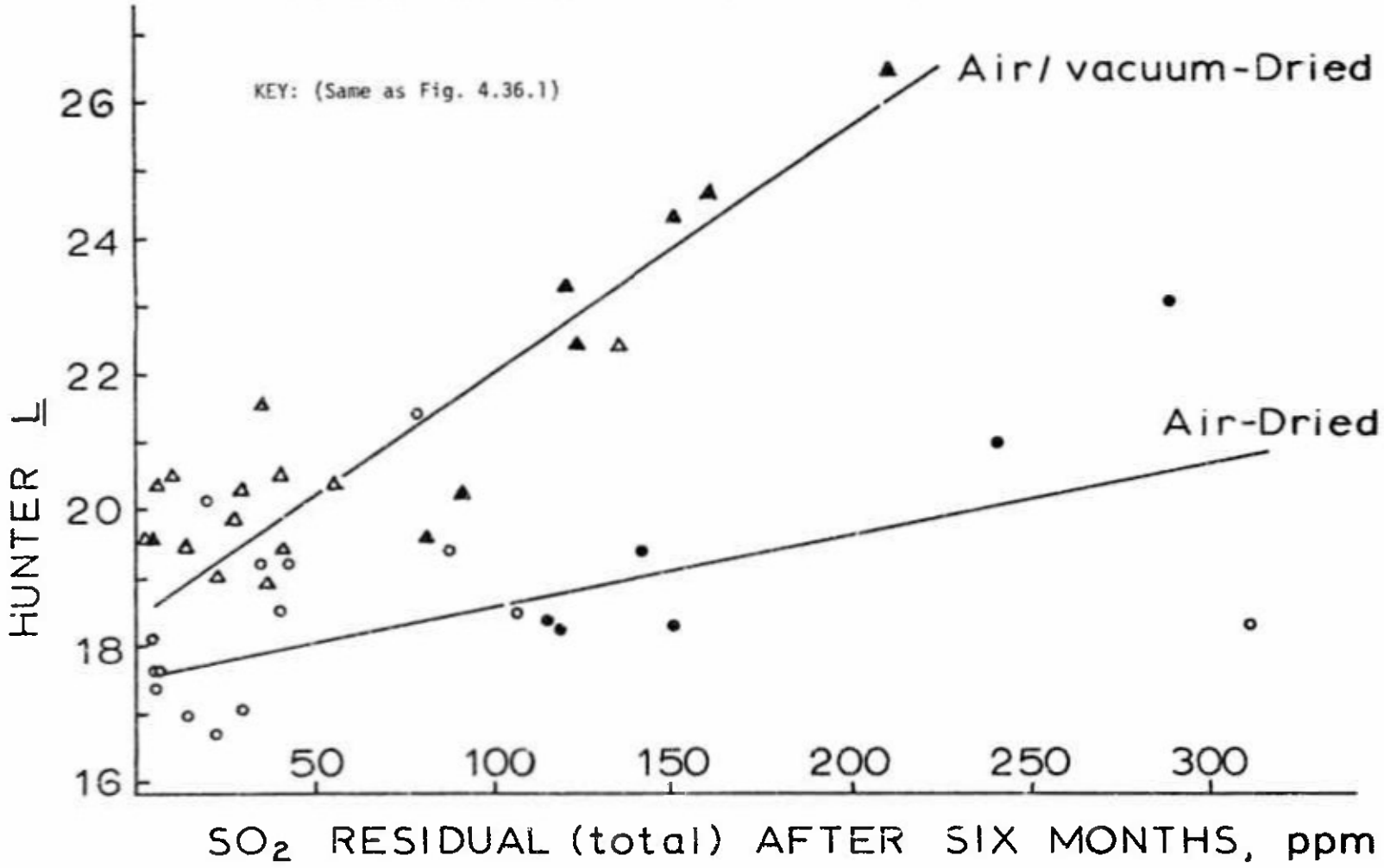


FIG. 4.36.2 EFFECT OF THE HIGHER SULFITE RESIDUALS OBTAINED BY GAS TREATMENT ON CHERRY COLOR (Hunter L, or brightness) AFTER SIX MONTH'S FROZEN STORAGE.



4.37 Comparison of Drying Methods - The three modes of drying used on cherries - air-, air/vacuum-, and freeze-drying - represent increasingly lengthy and expensive alternatives which subject the fruit to progressively lower mean drying temperatures that should better protect product color and flavor. Practical drying rates are maintained at these lower product temperatures typical of vacuum- and freeze-drying by the application of vacuum. When the product temperature remains below freezing during drying, the prevention of shrinkages (collapse of cell structure) becomes an added advantage in that rehydration characteristics are improved. A documentation of these differences in the present instance is shown in Table 4.37.1.

TABLE 4.37.1 COMPARISON OF DRYING METHODS - CHERRIES, 1971[a]

	Air-dried	Air/vacuum-dried	Freeze-dried
Drying time, hr	6	10	36
Maximal product temp., °F	160	125	95
Bulk density, kg/l.			
Final moisture, %	15-20	3-9	1-4
Color: Hunter a	8-12	10-17	13-19
L	17-20	19-25	21-27
Subjective ratings:			
color	1.3	4.2	5.4
odor	1	2.3	6.0
Recovery (rehydration), %	36.9	36.9	41.6
Bulk volume (rehydrated), ml/g	1.67	1.86	2.21
Texture (rehydrated), kg	85	70	63

a) B,C,D - lots stored at 100° only.

The drying times and maximal product temperatures shown here are typical of good operation of the respective types of equipment, representing a compromise between productivity and product protection. Lower or higher product temperatures could have been realized, which would have correspondingly altered the drying times. This would have also changed the parameters

of product quality presented here for better or worse, respectively. Ranges are given for final moisture and objective color to show the overlap experienced between drying methods; median values could be used as typical here, or means calculated from data given in the Appendix. Subjective ratings of color and odor are averaged for samples stored at 100°F only, since there was little difference among the frozen controls. As indicated by ratings close to the bottom of the scale (1), the air-dried samples held at this high storage temperature were very bad indeed.

Rehydration of these three types of dried products showed somewhat less dramatic differences. The recovery of rehydrated weight, based on fresh product entering the dryer, was low (36-42%) for all of the products, including freeze-dried. This value depends very much on the method of rehydration, but the one employed here seems reasonably practical. In the most usual use of red tart cherries - a pie-filling - the plumpness, or volume occupied by the fruit is even more important than the drained weight. The bulk volume measurement used here shows that the less shrinkage noted (lower bulk density) in the dried fruit due to the less harsh drying milieu encountered in vacuum- and freeze-drying was carried over into the rehydrated product, wherein air/vacuum-dried cherries provide greater bulk volume (1.86 ml/g) than air-dried (1.67), and the freeze-dried cherries greater yet (2.21). As usual, the texture of rehydrated material depends on the degree of rehydration, and we find the resistance to compression and extrusion, measured with the Instron universal testing machine, varying inversely with recovery and bulk volume from 85 kg for the slightly tough air-dried fruit down to 63 kg for the more tender freeze-dried material.

In Table 4.37.2 data on the retention of SO_2 after drying and after storage are given for each drying mode and most sulfite treatments. Completely comparable sulfite treatments are not available, but air-drying is first compared to freeze-drying and in part to air/vacuum-drying for similar dip pretreatments and then to the latter for equal dipping and gas treatments. As expected, more than twice as much SO_2 was retained during freeze-drying, despite the lower moisture attained. However, the results are not so clear-cut when comparing air/vacuum-drying with air-drying. Air/vacuum-drying retained slightly more SO_2 from dipping treatments but less - and more consistently so - from gas treatments. No reason for this turnabout can be suggested.

TABLE 4.37.2 COMPARISON OF DRYING METHODS WITH RESPECT TO SO_2 (total) REMAINING IN CHERRIES AFTER DRYING AND AFTER STORAGE, 1971

SO_2 Treatment, ppm (Pre-drying/Mid-drying)	SO_2 Residual after drying, ppm			SO_2 Residual after storage,[a] ppm		
	AD	AV	FD	AD	AV	FD
Dip treatments:						
2000/ -	9	na	na,38	15	23	42,36
4000/ -	29,23		-	20,30	29	-
5000/ -	-		86,87,91	-	-	82,86,86
10,000/ -	78,120		-	75,108	36	-
Av.[b,c]	52	-	76	50	32	67
4000/4000	36,42	na,51	-	41,40	30,56	-
- /4000	5,11	8,15	-	6,7	14,8	-
- /7000	30,35	na,73	-	36,(312?)	40,36	-
Av.[b]	26	45	-	28	31	-
Gas treatments:						
4% / 2%	125,129	88,104	-	116,118	81,124	-
- / 2%	162,132	91,103	-	141,151	93,119	-
- / 3%	203	128	-	242	150	-
- / 4%	238,-	156,128	-	289, -	160,210	-
Av.[b]	175	114	-	192	134	-

a) "A" storage samples only (@ -35°F)
b) Missing or questionable data supplied to provide comparable averages
c) Averages not strictly comparable, but illustrative.

4.41 Results with Green Bell Peppers in 1970 - A wide range of results was obtained in the drying of peppers during the 1970 season (see Table 4A.3.56), but in no case was good quality retained throughout six-month's storage at 100°F. Apparently, excessively high moistures and, except in lots FD 13-15, very low sulfite residuals were contributing factors. The normal green color, retained very well at -35°F or even at 75°F in many cases, was variously tinged with brown in products stored at 100°F. Hay-like, and even in extreme cases tobacco-like, odors replaced or overshadowed the characteristic and desirable green pepper odor as a result of severe drying or storage conditions.

Only minor differences were noted in the uptake of SO_2 over sulfite pretreatment times of 2 - 8 min and concentrations of 2,000 and 4,000 ppm SO_2 in lots FD07-09 and FD13-15. However, when the sulfite solution was made up with $NaHSO_3$, in place of dissolving SO_2 gas in water to give H_2SO_3, and to twice the level of sulfite ion employed with the latter to compensate roughly for the difference in activity due to pH, greater SO_2 residual and consequently better protection of color were obtained.

An attempt to retreat the product after freeze-drying with gaseous SO_2 in lots FD20-21, as with cherries, proved ineffective. The pick-up of SO_2 by the dry material was not sufficient to protect against oxidation. Both color and odor were adversely affected as before.

A slight improvement in the air-dried product was noted when high drying temperature was avoided, rather than merely programmed downward during the course of drying. In this respect, a constant temperature of 150°F proved slightly better than 170°F, as in lots AD02 & 03. However, use of the lower drying temperature increased the drying time from 95 to 145 min. Sulfite pretreatment was somewhat effective in maintaining color stability in the air-dried product during storage, even though the residual (10-30 ppm) was low.

One lot, VD05, that was entirely vacuum-dried with a shelf temperature of 180°F and a final product temperature of 120°F had nearly as good a color as a freeze-dried product, even without pretreatment. The low level of oxygen present during vacuum drying is probably a factor in this. Products given a preliminary air-drying to 80 - 90% weight reduction to shorten drying time gave products inferior in color and odor to that wholly vacuum-dried. This result emphasizes the fact that air-drying differs from vacuum-drying on two important counts - contact with higher levels of oxygen and at

higher ambient and product temperatures. The longer drying time required in vacuum-drying is apparently not harmful since the exposure is at low partial pressure of oxygen (1 mm Hg, or 1/150th of atmospheric) and low-to-moderate temperature (50-150°F).

4.42 Results with Green Bell Peppers in 1971 - Diced pepper, with and without sulfite pretreatment or interstage treatment, were air-, air/vacuum-, vacuum-, or freeze-dried. Samples were stored under nitrogen at -35 or 100°F with and without desiccant and evaluated for product quality. The data are shown in tables 4A.3.47-55 of the Appendix.

Pretreatment by dipping in 4000 ppm SO_2 (as $NaHSO_3$) gave greater total sulfite after air-drying and storage (251 ppm) than did the same concentration of dip as H_2SO_3 (80 ppm), comparing the samples of greatest interest - "C" (packaged with desiccant and stored at 100°F). Air/vacuum-drying with an interstage dip in 4000 ppm SO_2 (again as $NaHSO_3$) resulted in an even greater residual (373 ppm). But the highest residuals (403-526 ppm) realized in interstage treatment during air/vacuum-drying were obtained by gas treatment with 4% SO_2.

The only effect noted from varying intermediate weight reduction in air/vacuum-drying was an increase in bulk density when the air-drying stage was prolonged. This was true whether accompanied by interstage treatment with gaseous SO_2 or not.

In Tables 4A.3.49 and 54 the more negative values of $\bar{a}$ indicate a greener color, and positive values of $\bar{a}$, a decided degree of browning. In this respect, dipping pretreatment in $NaHSO_3$ before air drying was somewhat more effective ($\bar{a}$ = -6.8) than none ($\bar{a}$ = -5.4) or than the same level of treatment in H_2SO_3 ($\bar{a}$ = -3.6). In protecting color during subsequent storage. However, there was no difference in brightness (L) between the treated and untreated. Packaging the diced pepper with desiccant helped dramatically in preserving green color in both air-dried ($\bar{a}$ = -4.6 vs. +1.2) and air/vacuum-dried ($\bar{a}$ = -4.1 vs. +2.0) products during the 100°F storage. The colors were also brighter on the average in both air-dried (L = 31.3 vs. 28.8) and air/vacuum-dried (L = 27.9 vs. 25.3) peppers.

According to objective color measurements, the air-dried peppers were both greener and brighter than those air/vacuum-dried. This is surprising in view of the higher SO_2 residual in the latter. The air-dried product also had a somewhat

lower bulk density (.187 vs. .237 kg/l.), indicating slightly less shrinkage - also unexpected. However, diced pepper that was solely vacuum-dried had lower bulk density (.150 kg/l.) than either. The reason for the greater shrinkage and therefore higher bulk density in the air/vacuum-dried product is not known.

It is especially important to note that air-dried and air/vacuum-dried peppers held in frozen storage as controls had generally normal and acceptable color and odor, whether treated with sulfite or not. Moreover, sulfite treatment, at least at these levels, was ineffective in preventing deterioration of the dried products at 100°F in the absence of in-package desiccation. The levels of SO_2 remaining after six-month's storage @ 100°F were too low (<20 ppm) to be useful in this regard. Dried peppers packaged with desiccant, however, were another story. Sulfite was retained almost as well as in frozen storage, as was product quality. There was a slight difference in keeping quality among AD-, AV-, and VD-lots between these two storages, depending on whether sulfite treatment was given or not, and this is best exemplified by the sensitive a values:

	Samples stored with desiccant @		
	-35°F	100°F	Difference
Average of 10 untreated lots	-5.3	-4.6	.7
Average of 6 lots treated with SO_2 ($NaHSO_3$)	-6.0	-5.8	.2

Free sulfite residual probably remained high enough (401 ppm) in lots VD04, pretreated with 4000 ppm SO_2 (as $NaHSO_3$) and packaged with desiccant, to be effective in helping to preserve product quality; but even untreated vacuum-dried pepper remained acceptable after storage when packaged with desiccant. However, sulfite residual in the pretreated product packed without desiccant was only 35 ppm, and color and odor deteriorated below acceptable levels.

In freeze-dried peppers sulfite treatment was partially effective against browning during storage at 100°F. Some improvement in both a and L readings was noted in lots FD04-9, which were subjected to $NaHSO_3$-dip, although the corresponding increase in subjective rating of color and odor was marginal. No treated lots remained acceptable at 100°F regardless of treatment unless packaged with desiccant. The average a-reading (greenness) improved from -5.9 to -10.3 in freeze-dried

peppers stored at 100°F when packed with desiccant, while the L-reading (brightness) increased from 47.1 to 48.4. Both parameters of color were in this instance about equal to those observed in products stored frozen, as noted in the other dried peppers. Subjective ratings of color and odor were slightly lower, but acceptable.

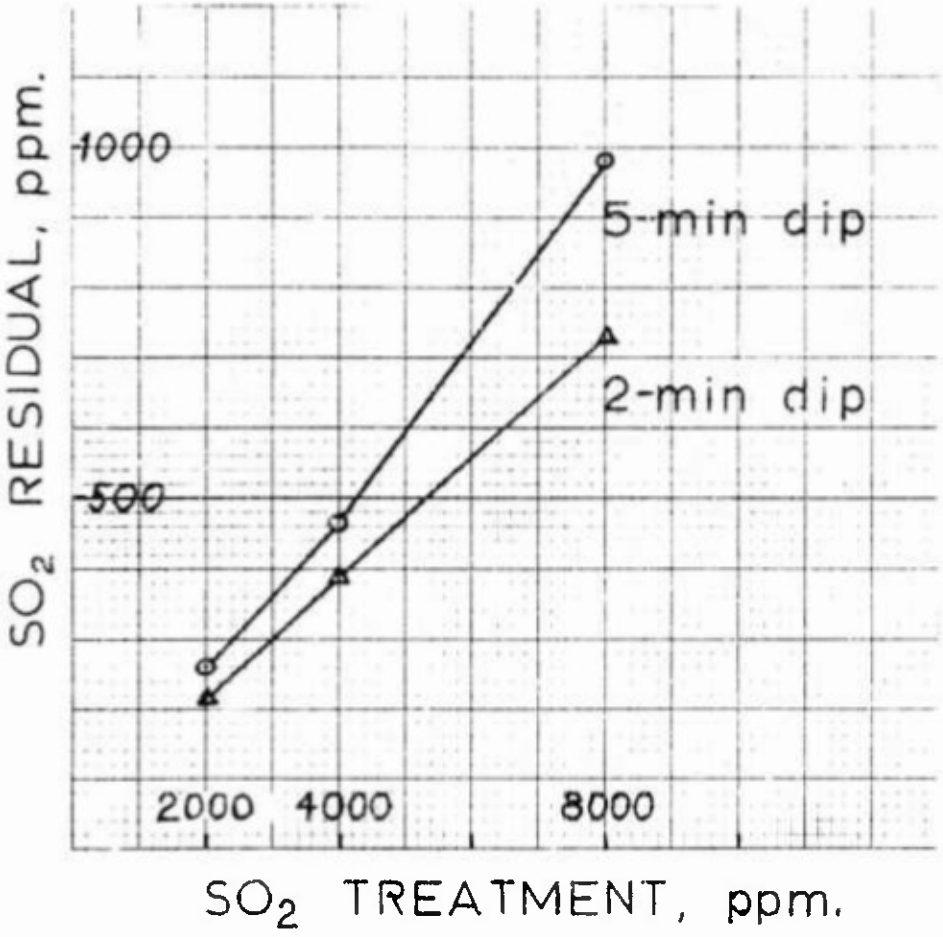
Again, dipping in H_2SO_3 (see FD03) resulted in relatively poor color and odor, albeit at low concentration of SO_2 (1000 ppm). And a 5-min treatment of the already dried product with 4% SO_2 gas in air apparently resulted in very little absorption, judging from the low residual - only 70 ppm total SO_2 after frozen storage and a negligible amount after storage at 100°F without desiccant. The protection obtained from these treatments was nil.

In every case, the expected advantage to be derived from sulfite treatment at these low but practical levels has been absent or small. The inescapable conclusion is that, in dried pepper as in dried cherries, low moisture content - as determined by in-package desiccation, is much more important to keeping quality than is sulfite level.

The effect of dip time and concentration on sulfite residual is demonstrated by lots FD04-9. Although there is some unexplained discrepancy between residuals found before and after storage, as experienced elsewhere in this study, the relative pick-up can be assessed from the average residual in samples stored frozen, with or without desiccant, as shown in Fig. 4.42. The response to greater dip concentration in terms of SO_2 residual after frozen storage, is linear for both 2- and 5-min dips times. However, the increased absorption of SO_2 obtained from prolonging the dip from 2 to 5 min is much less than proportional. This clearly show that higher concentration is more effective than longer dip time in increasing the SO_2 residual in diced pepper.

4.51 Results Obtained with Dried Apples (1970) - The dehydration of 47 lots of apples was carried out during the 1970 season, using the newly introduced processing variety, Mutsu - a yellow-green apple with processing quality midway between the two standard sorts, Rhode Island Greening and Golden Delicious. Peeled apples were either sliced radially into 16 wedge slices per apple or cut into 3/8" dices. In either case the freshly cut product was passed over a 5/16" vibratory screen to provide a more uniform size distribution for drying. The pieces were treated to control browning both at the surface and also in the piece centers where, during air-drying, product temperature could rise into the

Fig. 4.42 SO_2 Residual after Frozen Storage as a Function of Treatment.



critical range just below that necessary to inactivate the polyphenolase. Pretreatment was carried out by dipping the freshly cut product for from 2 to 5 min in 3 volumes of solution, variously 1 - 3% NaCl or 1,000 - 3,000 ppm SO_2, usually as $NaHSO_3$. These variables along with the final percent weight reduction are listed in Table 4A.3.57.

Threatment with NaCl was investigated as an alternative to SO_2 when it was noted that a practical, if not complete, level of control of browning was obtained in the usable range 1 - 3%. Above this level the residual might be excessive from the standpoint of flavor. This treatment provided a toughening of the slice surface, instead of softening, which was in marked contrast to the usual effect of SO_2. Since the Mutsu variety undergoes browning only at a moderate rate, relative to many processing varieties, and since the processing was carried out very late in the season (March-April), conditions were such as to favor this particular substitution of enzyme-inhibiting chemical additive. It is fairly certain that the substitution of NaCl for SO_2 would not be appropriate for the R.I. Greening or Northern Spy - both rapid-browning varieties - in early-season processing, except perhaps at higher levels.

Typically, the browning was eliminated by the lower levels of treatment less readily at the center of the pieces than at the surface, and in the fibrovascular bundles near the core tissue less readily than elsewhere. Control of browning was more easily achieved in the smaller pieces such as the 3/8" dices as against the more bulky slices.

Finally, the inhibiting effect of SO_2 was more persistent than that of NaCl, as was particularly noticeable during rehydration. Apple pieces treated with NaCl could be rehydrated to a light-colored product in a hot rehydration where the dried pieces were quickly elevated to a temperature (180°F) sufficiently high to inactivate the enzyme system thermally. But the marginal enzyme inhibition that NaCl provides could not be relied upon to prevent browning during a cold rehydration. This is due to incomplete penetration of the NaCl to the piece centers - even small pieces, to a degree of damage caused by shrinkage throughout the tissue rather than merely at the cut surface prior to drying, and to dilution of the inhibiting chemical even at the piece surface during rehydration. We had noted this same effect in earlier work on the dehydrofrozen apple pieces. An individually quick frozen product, such as we obtained by freezing the product right on the dryer trays, was a distinct advantage during rehydration in obtaining a quick thermal inactivation within a minute or so of removing the pieces from a sub-freezing environment.

Product bulk densities noted in Table 4A.3.57 indicate a slight packaging economy for dices over slices in that they provide a greater weight of product in a given volume. The bulk densities of the air- or vacuum-dried products (.14 - .28 kg/1.) were 3 to 4X as great as freeze-dried (.06 - 0.9 kg/1.). Since the more dense and shrunken product has a lesser rehydration capacity, this may not be an overall advantage, particularly if the freeze-dried product could be compressed without injury. The dried apple dices and slices were rehydrated by two different methods - one cold and the other hot, in recognition that either might be used in practice. In the first, 20 g of dried apples was rehydrated with 10 parts of water at 70°F for 1-1/2 hrs (freeze-dried product) or 4 hr (air-dried) in 400-ml beakers. In the hot method the same proportion of 190°F water was added and the mixture allowed to stand and cool for one or two hr, respectively.

Surface erosion, or sloughing, in a hot-rehydrated apple sample was determined by first mechanically shaking it with its rehydration liquid diluted to a total volume of one l. An Eberbach shaker operated at 100 rpm for 30 sec was used for this. After pouring off the liquid and suspended solids into a sedimentation cone, the eroded material was read after 60 min as the volume of sediment in ml.

The effect of treatment level (with NaCl or $NaHSO_3$) and mode of drying (air- or freeze-dried) on rehydration characteristics is shown in Table 4.51, averaging data from sliced and diced product and from both rehydrations. The relative toughening effect of treatment with NaCl vs. the usual softening effect of sulfite treatment is clearly seen in terms of firmer texture, less sloughing, and slightly greater bulk volume. The freeze-dried products rehydrated more completely while maintaining greater bulk volume, but at the expense of softer texture and greater sloughing. Finally, there is a noticeable trend - though undoubtedly lacking in statistical significance in these limited rehydration tests - for higher treatment levels of NaCl to firm the tissue progressively more, and for SO_2 to soften it. Otherwise, no consistent effects arising from treatment level of either were observed.

TABLE 4.51 EFFECT OF TREATMENT LEVEL (WITH NaCl or $NaHSO_3$) ON REHYDRATION CHARACTERISTICS OF AIR- AND FREEZE-DRIED APPLE PIECES (1970 Pack)

TREATMENT I	% NaCl:	1	2	3
Bulk Volume, ml:[a]	air-dried	153	152	158
	freeze-dried	209	200	206
Sedimentation, ml:[a]	air-dried	13	11	12
	freeze-dried	13	12	12
Texture, kg:	air-dried	54	70	75
	freeze-dried	20	20	25
Rehydration, %:	air-dried	59	59	59
	freeze-dried	84	83	83
TREATMENT II	ppm SO_2 (as $NaHSO_3$)	1,000	2,000	3,000
Bulk Volume, ml:	air-dried	146	147	154
	freeze-dried	196	192	199
Sedimentation, ml:	air-dried	19	17	18
	freeze-dried	20	32	30
Texture, kg:	air-dried	38	38	35
	freeze-dried	21	12	16
Rehydration, %:	air-dried	62	60	58
	freeze-dried	82	84	82

a) Volumes obtained from the rehydration of 20-g samples of dried apples.

4.52 Results with Dried Apple Pieces (1971 Pack) - The special emphasis placed on the sulfiting and drying of red tart cherries in 1971 did not permit a continuation of the similar work on apple, begun in the previous season. In lieu of this, some samples of air-dried apple dices (code: 71NAP-) produced in a concurrent study of drying rate were provided as examples of the type of product, acceptable in most respects, available using current technology. Some of these samples (AV01-05) were further vacuum-dried from the intermediate moisture stage (18-25%) to the lower levels (2-5%) at which the desired storage stability might be expected.

In these experimental lots the new variety Mutsu, well-ripened for several months in cold storage, was cut into 1/4", 3/8", and 1/2" dices, screened, and pretreated with 1500 or 3000 ppm of SO_2 ($NaHSO_3$) for 3 min at 70°F. The lightly sulfited dices were then air-dried, typically in two stages; first to 65% weight reduction at 200°F, followed by equilibration for 24 hr, and then to 86% weight reduction at 180°F. Due to a pick-up of moisture during pretreatment, this degree of weight reduction had been found to provide a moisture level about equal to the commerical dried apple (24%). This depended on the dice size, however, and the smaller 1/4" dices, having a greater surface-to-mass ratio and smaller interstitial spaces, picked up considerably more moisture and gave a wetter product (29%) at the same weight reduction. Other effects noted were the longer drying time required and less uniform drying experienced when a between-stages equilibration was not practiced, and the slower finish drying experienced with the larger 1/2" pieces. Data on these lots are given in Table 4A.3.58. None of these samples were subjected to storage tests since termination of the project would have intervened.

4.6 CONCLUSIONS AND RECOMMENDATIONS

4.61 Red Tart Cherries - The best quality of dried cherry is still obtained by freeze-drying, but the most practical (economical) method may be a combination of air- and vacuum-drying. In this two-stage process 75% of the moisture removal (or weight reduction) is accomplished rapidly (60-90 min) and economically in circulating hot air. Dry-bulb temperature shoud be programmed downward during the course of drying to prevent product temperature from rising so high as to invite thermal degradation of color and oxidation of flavor. Mixing of the bed of cherries is necessary during drying to prevent sticking to trays or apron. This is most easily accomplished in a continuous dryer composed of a cascading series of belts, each one feeding onto the next, although admittedly more expensive construction than a single belt.

The partially dried fruit, reduced in bulk about in proportion to weight reduction, is then transferred to the second stage of drying - in a vacuum shelf dryer. Here under reduced pressure of about 1 mm Hg and heated by radiation from closely spaced shelves (also subject to a schedule of decreasing temperature as drying progresses), the cherries may be dried to about 3-4% moisture in 8 hr additional. The product must then be bin-dried in desiccated air to lower moisture (1-2%) or packaged with sufficient desiccant to accomplish this important final stage of drying.

If the cherries are to be sulfited, this should be done during the interstage transfer from one dryer to the other, in the case of air/vacuum-drying. This avoids flushing away a greater part of the SO_2 originally absorbed with the hot air circulating through the fruit during the initial stage of drying. Also, to avoid rewetting and leaching soluble solids from the product at this stage, gas-sulfiting with a mixture of 2 - 5% SO_2 in air for up to 10 min is recommended, rather than dipping the partially dried fruit in an aqueous sulfite solution.

For freeze-drying, a conventional sulfite dip of the freshly-pitted cherries before preliminary freezing may give some slight improvement over an untreated product, though much of the absorbed SO_2 will be lost during prolonged exposure to vacuum, even at low temperature. For neither freeze-dried nor air/vacuum-dried cherries is it practical to sulfite the dry product just before packaging, as the pick-up of SO_2 by absorption or adsorption is apparently very slight in the absence of surface moisture.

Packaging under nitrogen is advisable to reduce the oxidation potential in the package, even though we were unable to demonstrate any great benefit from this procedure. But the removal of O_2 from the package is no substitute for low moisture level, which remains the most important factor in maintaining quality at elevated storage temperature.

In the red tart cherry we are dealing with a fruit having only a moderate amount of anthocyanin pigment, localized in a thin skin and susceptible to ready destruction. This limits its stability under the severe conditions of the usual storage test - six months at 100°F. The relative lack of success in this study in protecting color in the dried cherry during such storage suggests that this product cannot reasonably be made adaptable to adverse storage conditions, whether of high temperature or long duration. Indeed, it would be wise to keep such a sensitive product in refrigerated or at least cool storage. While higher levels of residual SO_2 can be imparted to the packaged product by stronger or longer sulfite treatment, this is likely to result in some irreversible bleaching of red color and a distasteful residual in the product as prepared for eating.

The application of food coloring during processing or utilization might alleviate the loss of red color during storage, but it would merely serve to mask to the eye, but not to the palate, other undesirable changes. A better alternative might be the selection of a cherry variety having a greater amount of natural pigment so that losses through degradation or bleaching would be relatively less serious, though the same objection regarding flavor changes might be valid. The most promising variety of this type, found in limited tests conducted at Geneva, is Olivet. This is reputedly a Duke type, having medium red flesh, but otherwise - unlike most darker red-fleshed Morello types - possessing the desirable flavor and firmness of the Montmorency.

4.62 Green Bell Peppers - Somewhat similar results were observed in the dehydration of peppers as in cherries, except that the technical problems were not so difficult. The cut surfaces of diced pepper do not bleed juice so readily as the pitted cherry, but do absorb SO_2 and give up moisture more readily than the waxy cherry skin. The smaller piece size obtainable by dicing is also an aid to rapid diffusion of both SO_2 and moisture between center and exterior of the pieces.[2] Drying time, in particular, was much shorter, despite higher initial moisture content (94%) of this low-solids material. Actually, the high sugar content of the

cherry interferes with the final stage of drying by reducing the equilibrium vapor pressure of water at the drying surface as the soluble solids become concentrated (3).

Again we find that adverse storage conditions rather than exposure to moderate drying conditions are the chief cause of deterioration in color and flavor, although avoidance of high product temperature during drying is still advisable. Pretreatment with SO_2 was only slightly more effective than no treatment in protecting the quality of dried pepper in the low moisture product obtained by in-package desiccation. Moreover, in the same 100°F storage tests sulfiting was ineffective in preventing deterioration in a higher moisture product. Greater residual SO_2 could have been imparted by stronger sulfite treatment ($\leq$8000 ppm), and this might have been more effective. However, as with cherries, the emphasis should be on reducing product moisture to low levels to insure preservation of quality under adverse storage conditions.

Because of the rapid drying obtained with diced pepper, making possible a more economical 16-hr drying cycle, freeze-drying may be the procedure of choice with this product. Since it is used in small amounts, more like a condiment than a major ingredient, the extra processing cost entailed in freeze-drying would not figure so heavily in the overall cost of a ration. On the other hand, the more complete reconstitution obtainable with a freeze-dried material may be less important in such a product, so that the shrinkage encountered in air - or air/vacuum-drying is less a disadvantage than in cherry or apple where recovery of bulk is desirable.

4.63 Apple - Less study was devoted to dried apple due to the limited time available and the lower degree of difficulty encountered with this product. Since apple is an inexpensive raw product (3¢/lb), freeze-drying is even less an economical alternative than with cherries or peppers. Like the latter, the extensive cut surface of diced apple permits ready absorption of SO_2 and rapid drying, but loss of solids and stickiness of the product are greater problems, more like cherry. In addition, when enzymatic browning occurs very rapidly, especially when the apple tissue is heated moderately as in the early stages of drying. Therefore, the protective action of SO_2 is required from the moment the product is

(3) LaBelle, R. L. 1966. Effect of sugar coating on drying rate. (Unpublished paper presented at the 2nd International Congress of Food Science & Technology, (Warsaw).

cut, as well as on through dehydration, storage, and reconstitution. When heated slightly (<150°F) or rehydrated slowly, browning will occur throughout the tissue and not just at the cut surface, so complete penetration of SO_2 is necessary.

Some limited success was obtained by treatment with weak (3%) solutions of NaCl, but the product was slightly, if not seriously off-color. Penetration of the antioxidant is much less rapid or complete than with SO_2, resulting in light brown piece centers. Reconstitution, in this case, would have to be accompanied by rapid heating sufficient to inactivate the enzyme system (180°F) and prevent a belated browning reaction.

Apple dices were readily sulfited by either dipping or gaseous treatment. Levels of 4000 ppm or 4% SO_2 should be adequate with treatment times commensurate with piece size. Pretreatment before drying is necessary.

Air-drying is only sufficient to produce a high-moisture product with poor storage stability from this high-solids material, so that air/vacuum-drying becomes the method of choice for a stable, low-moisture product. This drying procedure, unless greatly prolonged, would probably have to be supplemented by bin-drying with desiccated air or by in-package desiccation to reach the desired stability under severe storage conditions, but this was not investigated.

4.64 Summary of Recommendations - The recommended processing procedures for the three products included in this study are summarized in the following table:

	Drying Method	Sulfite treatment	Desiccation	under N_2	Stability at 100°F
Cherry	air/vacuum-dry	interstage with 4% SO_2	Yes	Yes	poor
Pepper	freeze-dry	optional	No	Yes	fair-good
Apple	air/vacuum-dry	pretreatment by gas (4%) or dip (4000 ppm, as $NaHSO_3$)	Yes	Yes	?

PART II - SULFITE ANALYSIS

4.7 EXPERIMENTAL PROCEDURE

The methods for SO_2 analysis described here were based upon the procedure of Ripper (1892) in which solid products were macerated and extracted with salt solutions. Comparisons between the "free" SO_2 determined by iodine titration and a new purge-colorimetric procedure described here for the first time were made using both model systems and dehydrated products.

4.71 Model SO_2 Solutions - Aqueous solutions of SO_2 were prepared in 0.025 M phosphate buffer with sodium bisulfite and stabilized against oxidation with ethylenediaminetetraacetic acid (EDTA) (0.001mM).

Phosphoric acid (25%) was used to adjust the pH of both aqueous solutions and extracts of dehydrated products. Model systems of "free" and "bound" SO_2 were generated by adding known amounts of acetaldehyde to the SO_2 solutions.

4.72 Preparation of Extracts - Extracts of dehydrated red tart cherries and peppers were prepared by adding water to dehydrated fruit to yield a sample equivalent to 100 g fresh weight, 10 ml of 0.5 M tartrate buffer pH 4.5 and 490 mls of aqueous sodium chloride (20% by weight) to a Waring blender. After blending for 5 min, this material was filtered thru 4 layers of cheesecloth and SO_2 analyses were performed on these extracts within 4 hrs.

4.73 I_2 Titrations - All iodine titrations were done using 50-ml samples in 125-ml Erlenmeyer flasks, 0.02N iodine solutions standardized with 0.1 N sodium thiosulfate, and 1 ml of 1% starch solution as an indicator. Burettes with 0.05-ml graduations were used to give a nominal accuracy of $\pm$ .02 ml. Reproducible and reliable endpoints were achieved by completing each titration within 15 to 30 sec.

"Free" SO_2 was determined by adding 6N HCl to each sample to stabilize the bound SO_2 before titrating. The amount of acid required was found to vary from one sample to another and the best results were obtained by adding sufficient HCl to yield a sample with pH 1.0. Total SO_2 was determined by first adding 2 mls of 1 N sodium hydroxide, waiting 30 seconds for the conversion of "bound" to "free" SO_2, then adjusting to pH 1 with 6N HCl before titrating with iodine. In order to dispel any dissolved oxygen a pinch of sodium bicarbonate was added before the iodine was added.

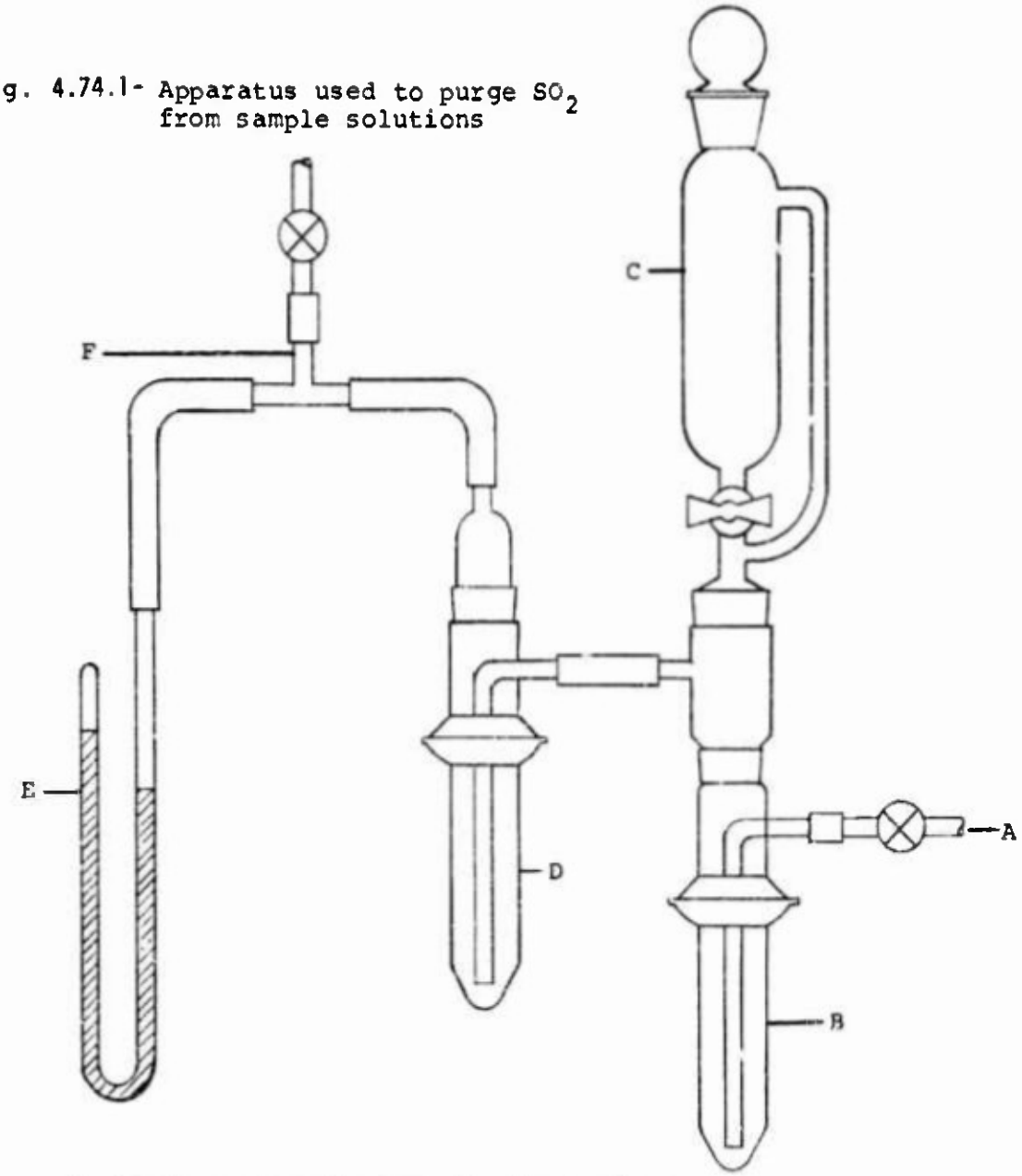
In titrating the extracts of the dehydrated products it was necessary to use a blank to determine the amount of iodine consumed by constituents other than SO_2. These blanks were found to be the sources of much of the discrepancies in the iodine trations discussed later in this report. Blanks were made by adding 1 ml of 40% formaldehyde to a duplicate sample and waiting 10 minutes before titrating with iodine. The formaldehyde presumably binds all available SO_2, and subtracting the number of mls of iodine consumed in this titration from the titration without iodine yields the net I_2 consumed only by the SO_2 in the sample.

4.74 Purge-Colorimetric Procedure - The purging of the SO_2 from the samples was accomplished using the apparatus shown in figure 4.74.1. This apparatus consists of: (A) a gas inlet controlled with a needle valve, B) a sample chamber, C) an acid reservoir, D) an absorption chamber, E) a manometer and F) a vacuum source controlled with a needle valve. The analysis was performed by placing a 10-ml ampule containing between 1 and 100 mg of SO_2 in the sample chamber. In the absorption chamber was placed 5 ml of 0.001 M 5,5'-dithiobis (nitrobenzoic acid) (DTNB) in 0.025 M sodium potassium phosphate buffer at pH 6.8 and an additional 15 mls of phosphate buffer. The acid reservoir was filled with 25% phosphoric acid (wt./wt.). The needle valves on the vacuum source (a water aspirator) and the gas supply were adjusted to yield a gas flow of 0.75 l. min and a pressure of 12 mm Hg in the system. Both helium and nitrogen were used as a purging gas with equal reliability. Even air in the laboratory will suffice if it is free of SO_2 contamination. Although the use of air eliminates the need for a gas cylinder and regulator and greatly simplifies the apparatus, this was not done in the experiments reported here, because of the possible contamination by SO_2 frequently present in the atmosphere of this laboratory. Then, 5 mls of acid was drained from the acid reservoir into the sample chamber and the purging continued for 2 min. After shutting off the vacuum source and allowing the pressure to come to atmospheric, the optical density of the absorption solution was measured at 412 nm. A standard curve prepared using this system and a sodium bisulfite solution standardized by iodine titration is shown in figure 4.74.2. Using the slope of this line (73.3 µg/O.D.) the SO_2 in the sample was calculated using the following equation:

$$SO_2 \text{ in ppm} = (73.3) \times OD_{412})/(\text{mls of sample})$$

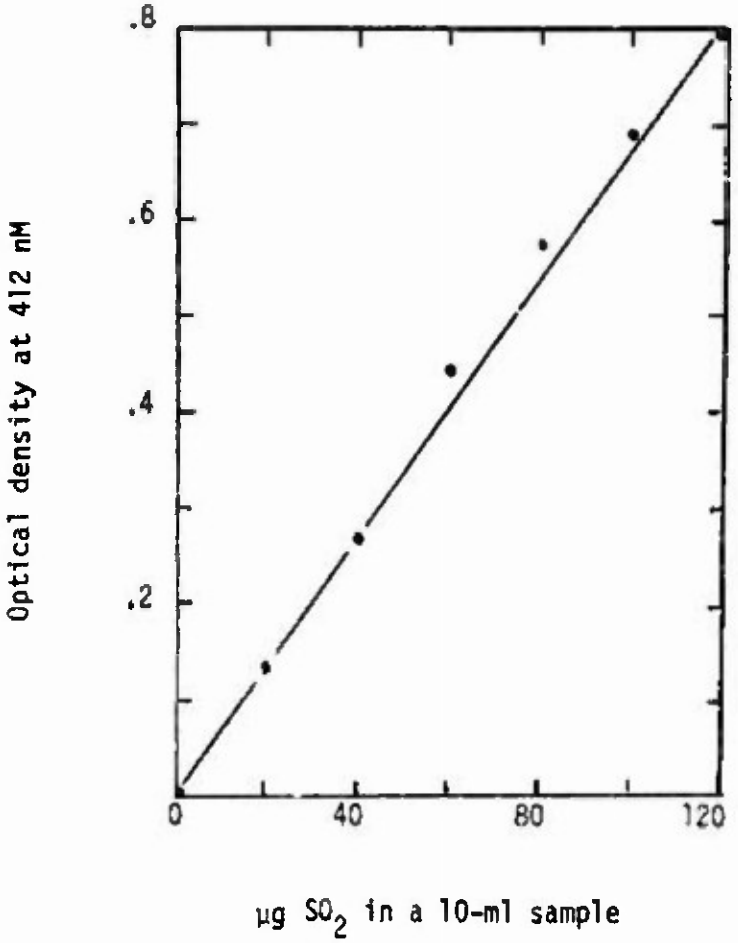
Because of the sensitivity of this analysis, the maximum SO_2 concentration which could be analyzed in a 10-ml sample of extract was 10 ppm. However, by diluting samples high in

Fig. 4.74.1- Apparatus used to purge SO_2 from sample solutions



A) a gas inlet controlled with a needle valve
B) a sample chamber
C) an acid reservoir
D) an absorption chamber
E) a manometer
F) a vacuum source controlled with a needle valve.

Fig. 4.74.2 A standard curve for the purging procedure showing the optical density at 412 nM versus the µg of SO_2 in a 10-ml sample



SO_2 with water, buffer or the solvent used for extraction, samples with a SO_2 concentration of as high as 5,000 ppm were analyzed.

4.75 Statistics - THe only statistical procedure used was a simple linear regression analysis for comparisons of the results of the two methods of SO_2 analysis.

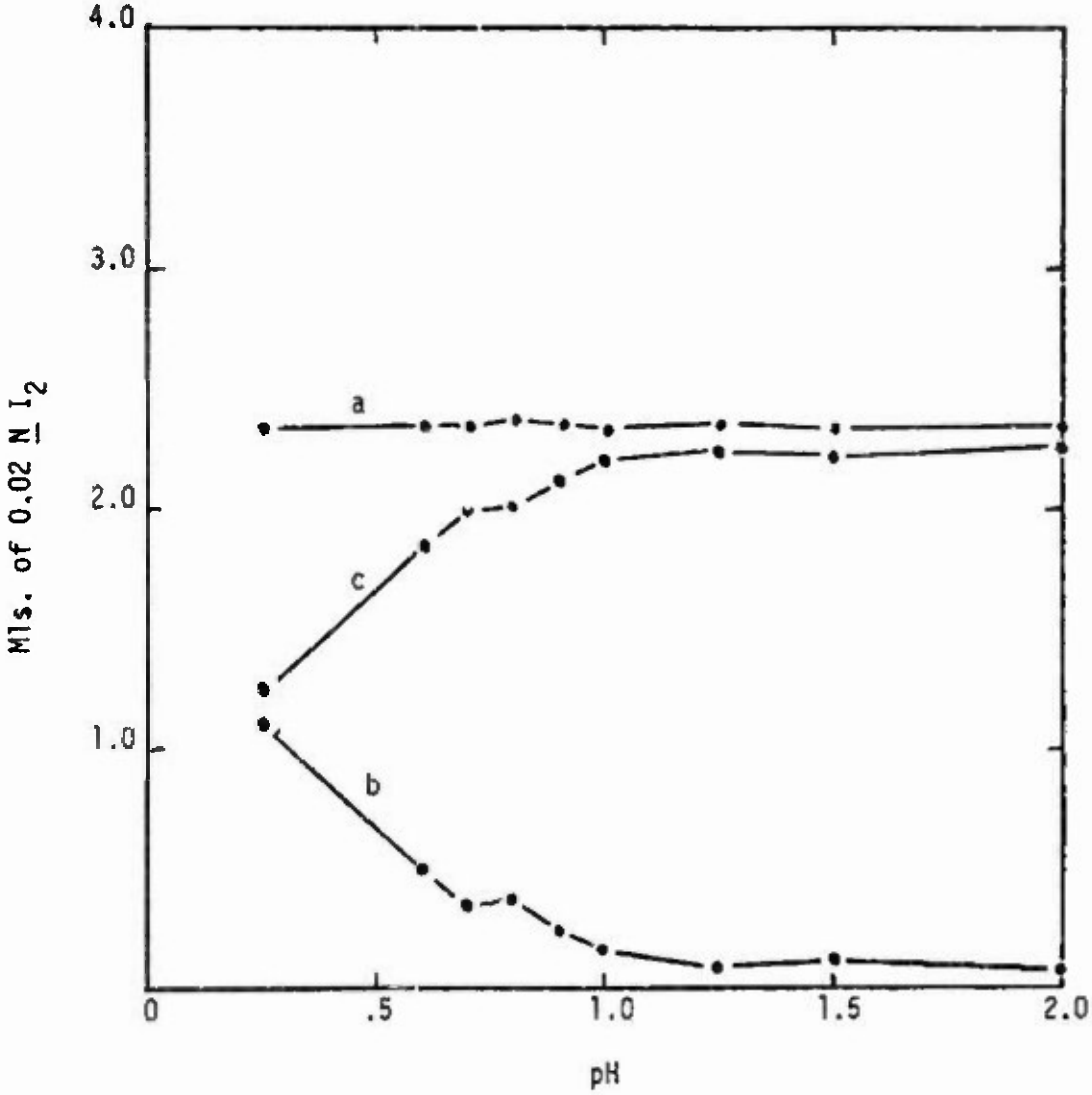
4.8 RESULTS AND DISCUSSION

The emphasis in the research reported here was on the examination of rapid, reliable and meaningful methods for the analysis of "free" SO_2 in natural products. Total SO_2 was determined to give information about the two methods of "free" SO_2 analysis studied. The concern for "free" SO_2 determinations resulted from the assumption that the "free" SO_2 present in a food product is that form of SO_2 responsible for the preservation action of SO_2.

Most methods for the analysis of free SO_2 can be roughly divided into three phases. First is the maceration and extraction of solid samples to produce solutions or extracts which are common to all analytical procedures for SO_2. Certainly considerable doubt exists about the relationship between the "free" SO_2 determined in these extracts and the "functional" state of the SO_2 in the solid samples from which they were extracted. This is particularly true for dehydrated food products which are extremely low in moisture. Unfortunately, a study of this phase of the analysis was beyond the scope of the work reported here. Secondly, "free" SO_2 determinations involve a procedure for the isolation of "free" SO_2 either chemically by the addition of acid to stabilize the bound or physically by distillation or purging to remove the SO_2 from interfering components in the sample. The final phase involves a chemical or physical procedure for quantitating the "free" SO_2. The discussions which follow are concerned with the last two phases of "free" SO_2 analysis as they are defined by two analytical procedures, direct iodometric titration and a purge-colorimetric procedure which is being reported here for the first time.

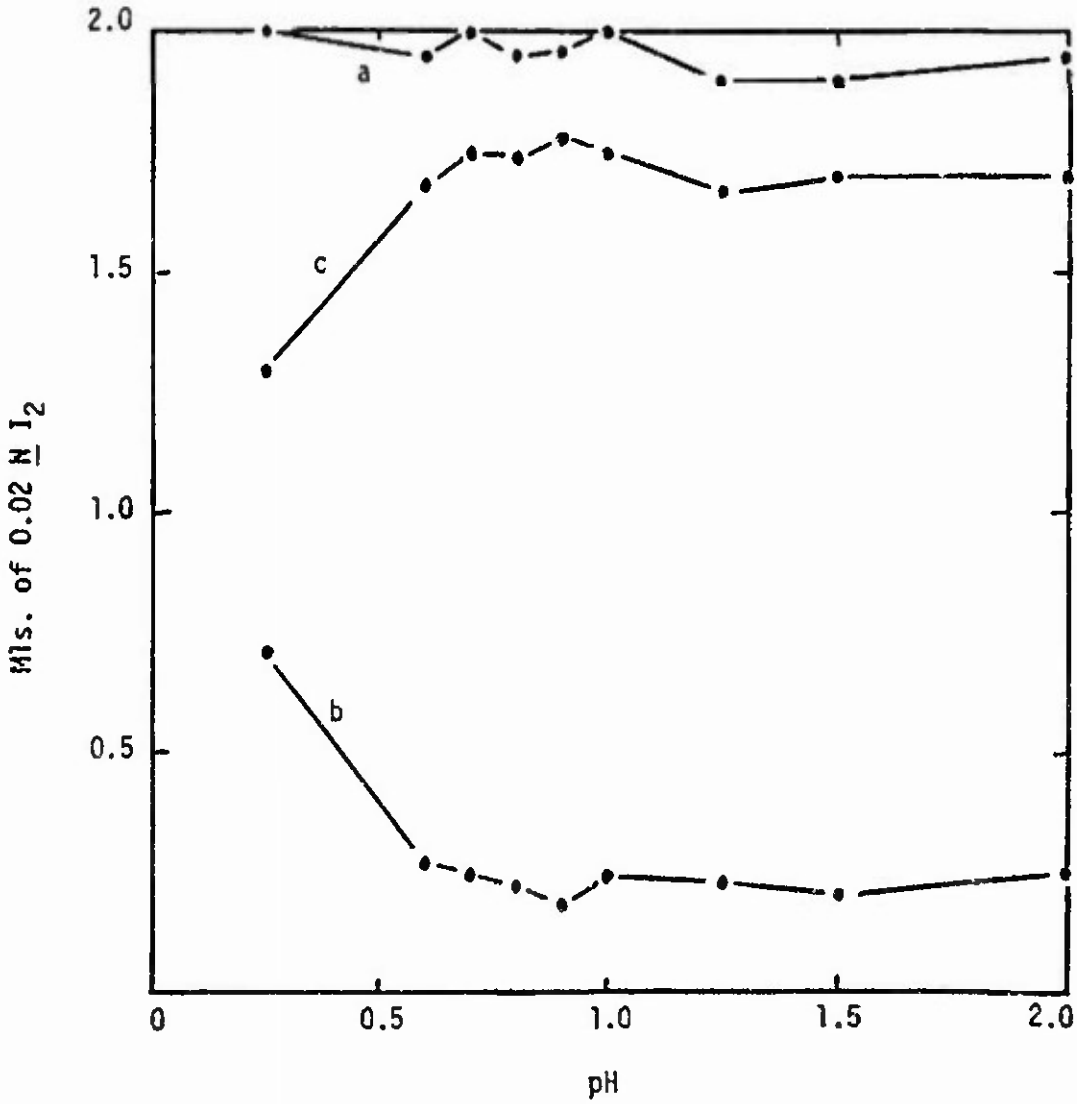
4.81 Effect of pH on I_2 Titrations - Prater et al. (1944) reported that pH has an effect on the amount of iodine required to titrate an acetone blank, and further that optimum results were achieved when the blanks were titrated between pH 2-3. These workers recommended that because the amount of acid required to achieve this range differs for each commodity the amount of acid should be determined for each commodity tested. Figure 4.81.1 shows the results of titrating a standard SO_2 solution with and without formaldehydre at different pH's in the range of pH 0.2 to pH 2.0. Clearly, titrating formaldehyde blanks below pH 1 yields results which are entirely too high, and acceptable results can only be achieved in the range of pH 1 to 2. Similar experiments using cherry, pepper, or apple filtrate containing a standard amount of SO_2 indicate that the optimum pH for these products is very close to pH 1 (figures 4.81.2-4). Therefore, all analysis in

Figure 4.81.1 A plot of the mls. of .02N Iodine required to titrate 180 ppm SO_2 phosphate buffer solution



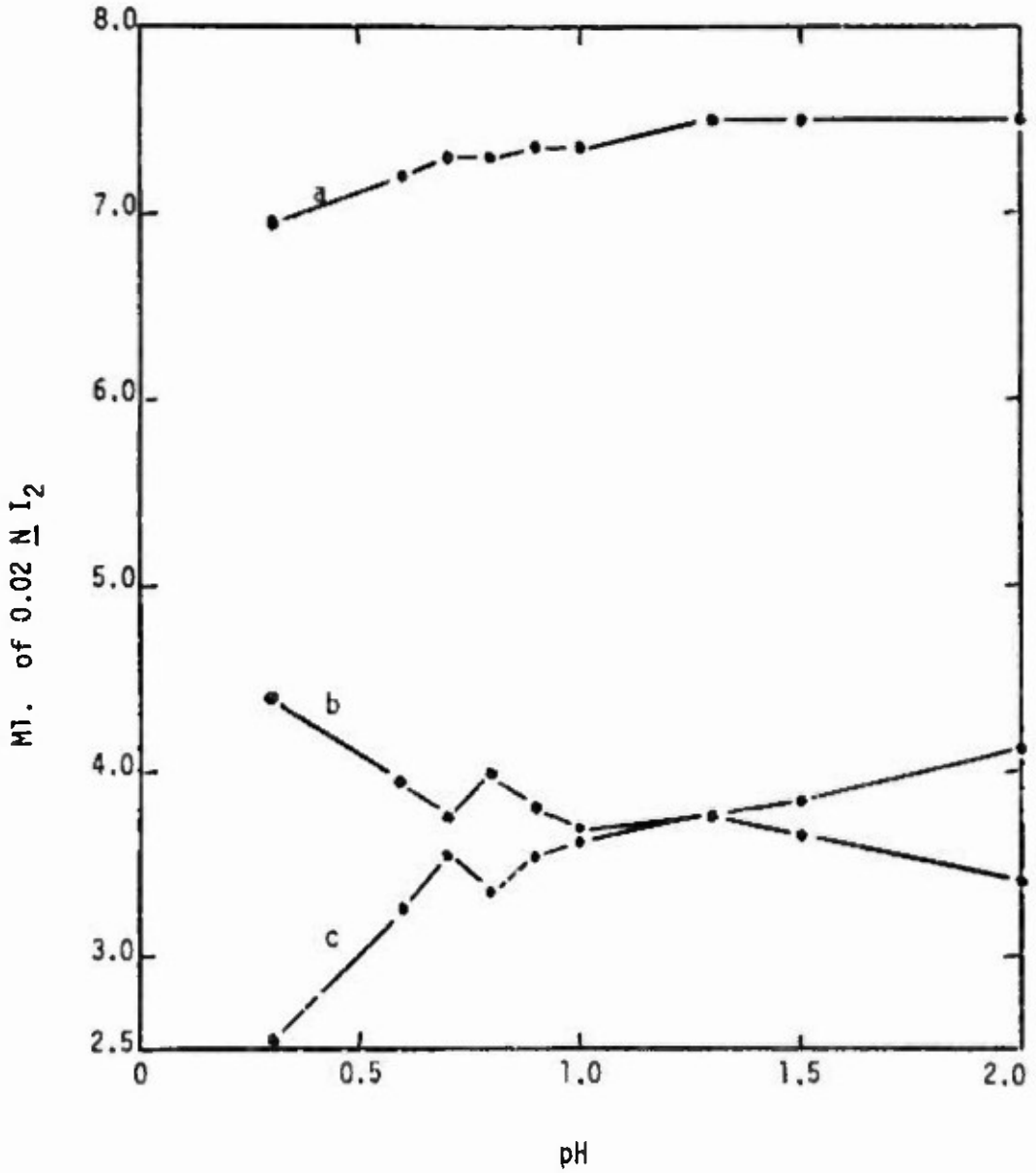
a) without formaldehyde added
b) with formaldehyde added
c) net or a - b

Figure 4.81.2 A plot of the mls. of .02N Iodine required to titrate a dehydrated cherry filtrate.



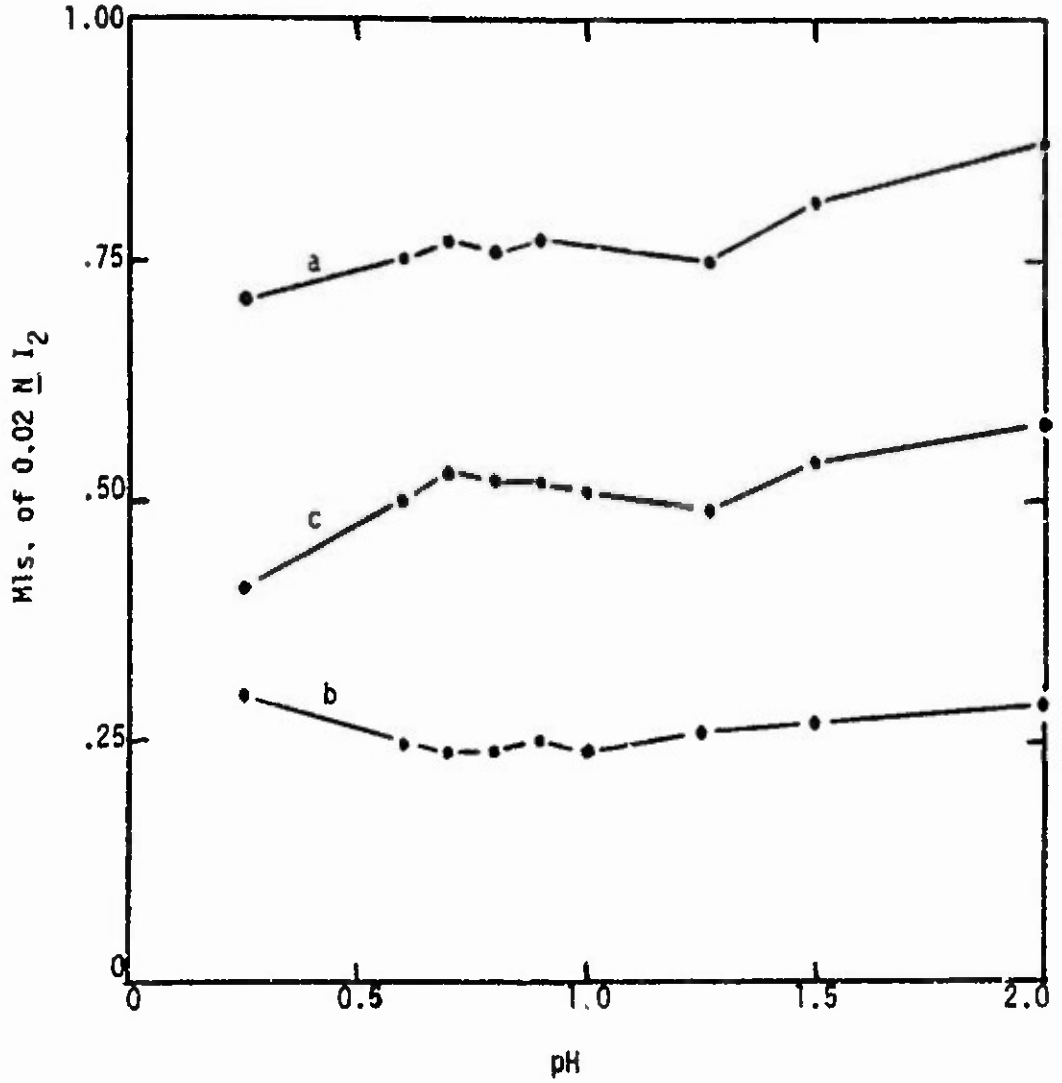
a) without formaldehyde added
b) with formaldehyde added
c) net or a - b

Figure 4.81.3 A plot of the mls. of .02N Iodine required to titrate a dehydrated pepper filtrate



a) without formaldehyde added
b) with formaldehyde added
c) net or a - b

Figure 4.81.4- A plot of the mls. of .02N Iodine required to titrate a dehydrated apple filtrate



a) without formaldehyde added
b) with formaldehyde added
c) net or a - b

this study were performed by determing the amount of acid required for each product which yields a pH of 1 before titration, not by adding a set amount of acid as is recommended in the method of Ponting and Johnson (1945).

4.82 Acetaldehyde - SO_2 Solutions as a Model for "Free" SO_2 Determinations

The theory of "free" and "bound" SO_2 is based upon the idea that SO_2 will combine with certain constituents of a complex natural product and produce a chemical complex or compound which cannot function as an antioxidant. Only the unbound or "free" SO_2 can protect the product from oxidation. Because SO_2 will react stoichiometrically with acetaldehyde to produce an α-hydroxy sulfonic acid, it was used as a model compound for "bound" SO_2. Using solutions of known SO_2 and acetaldehyde content the ability of the iodometric and purge-colorimetric methods to measure "free" SO_2 was examined. Figure 4.82.1 shows the percent recovery of SO_2 from a standard 50-ppm SO_2 solution at different molar ratios of acetaldehyde to SO_2. Theoretically, at a molar ratio of acetaldehyde to SO_2 of zero, 100% of the SO_2 present should be determined as "free". At a molar ratio of one, no free SO_2 should be present. This is more or less the case for SO_2 concentrations above 5 ppm. However, below 5 ppm SO_2 the results deviate somewhat from the theor.. Thus, free SO_2 in this system would be defined as that SO_2 which is in molar excess of the acetaldehyde in the system and both methods of analysis are equally effective for determining this "free" SO_2. The two advantages that the purge-colorimetric method has over the iodine titration method are the ability to measure "free" SO_2 as low as 0.1 ppm and the lack of interferences due to the presence of pigments and reducing substance other than SO_2. Figure 4.82.1 shows the high degree of correspondence between these two methods in the acetaldehyde SO_2 model system.

4.83 Discrepancies between the Two Methods Using Cherries and Peppers

The high degree of correlation observed between the results obtained by iodine titration and the purge-colorimetric methods using a model system was not found when these methods were applied to dehydrated cherries and peppers. For example, the linear regression equation obtained for the analysis of 140 samples of red tart cherries was:

$$FP = 1.67\ FI - 3.70, \quad r = 0.989$$

Fig. 4.82.1 Shows the % recovery of SO_2 from a 50-ppm SO_2 solution containing acetaldehyde versus the molar ratio of acetaldehyde to SO_2.

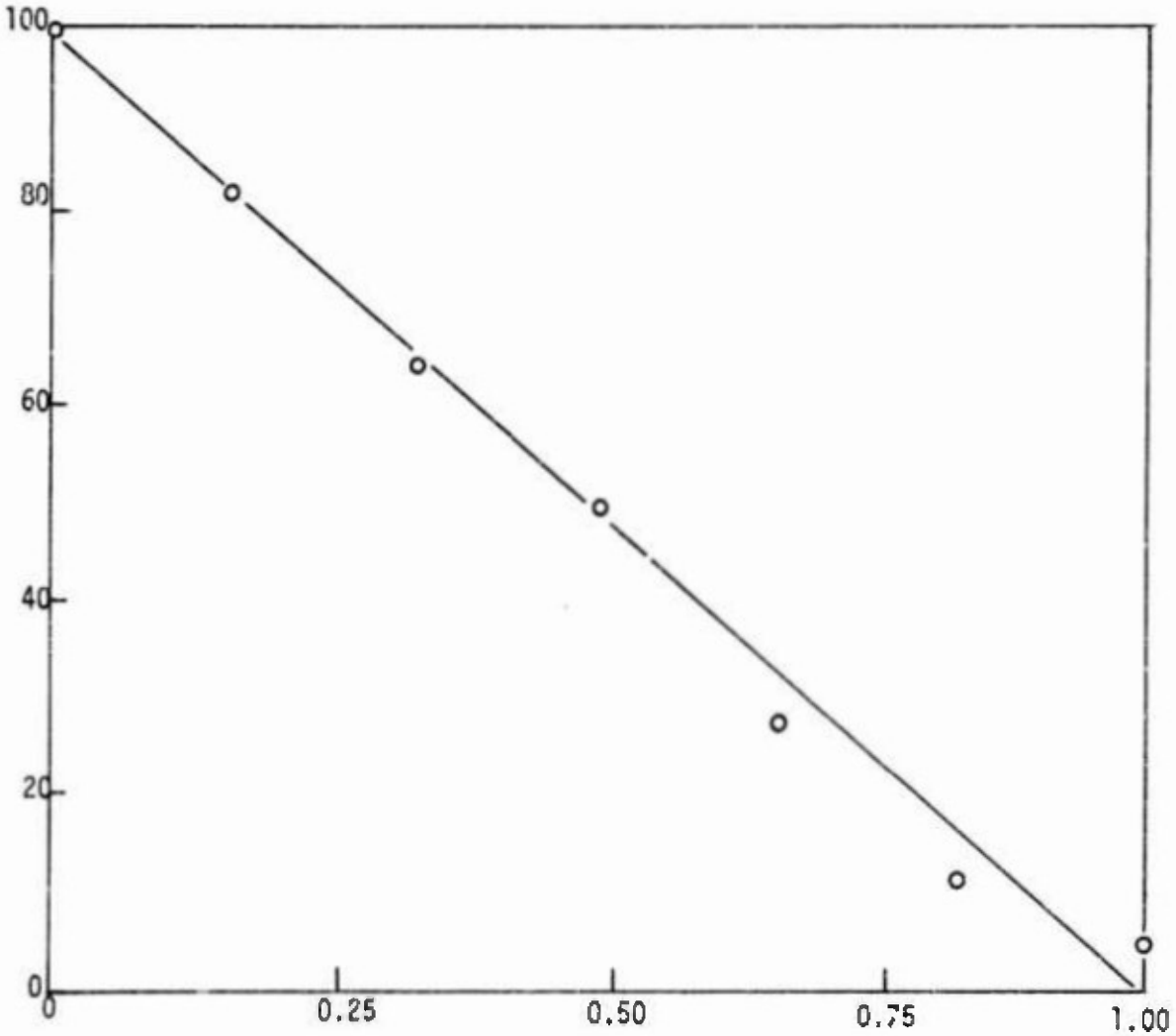
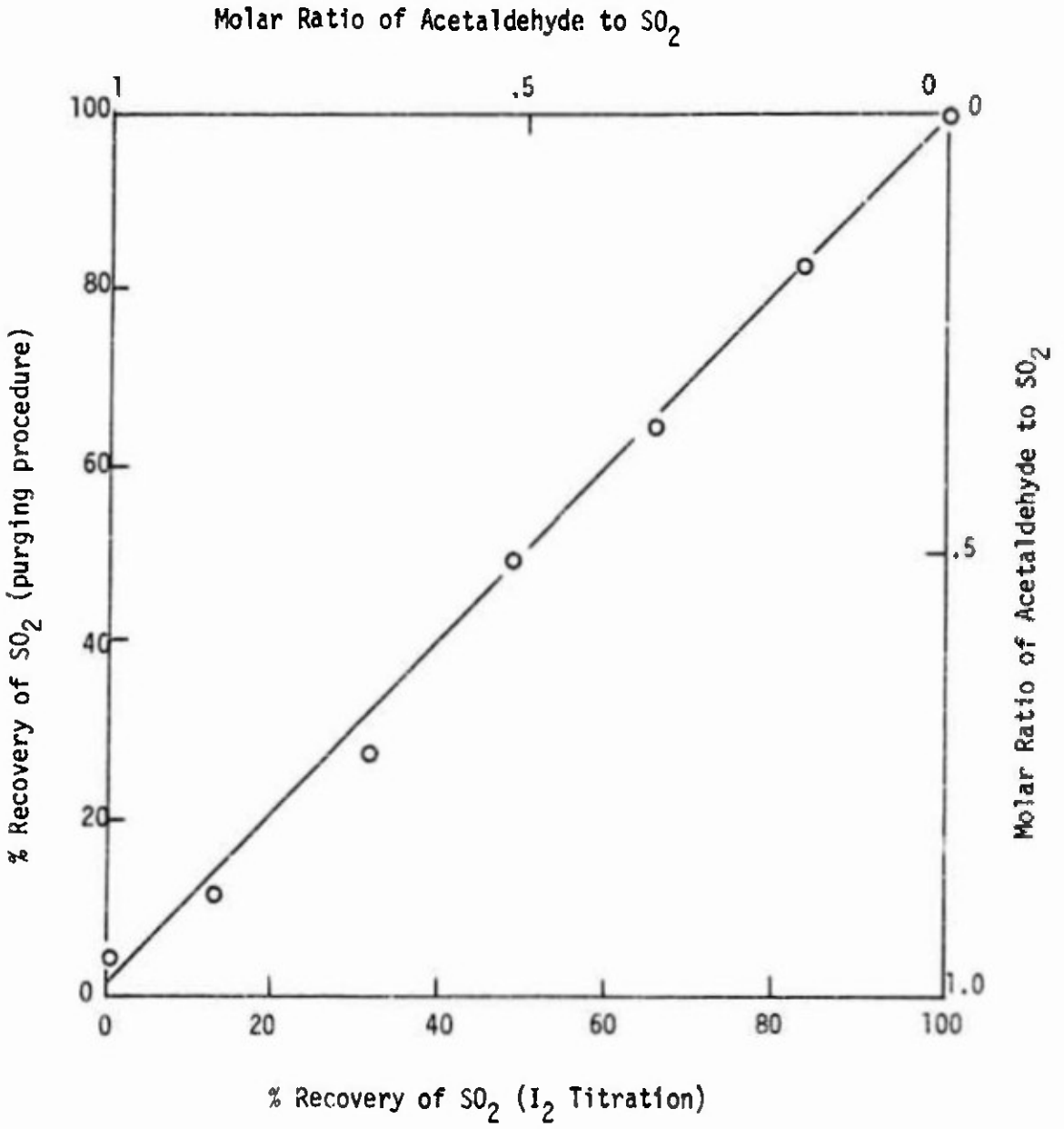


Fig. 4.82.2 Shows the % recovery of SO_2 using the colorimetric-purging method versus the % recovery of SO_2 using the Iodine titration method. These solutions contained different ratios of acetaldehyde to SO_2.



where FP is the "free" SO_2 determined by the purge method, FI is the "free" SO_2 determined by iodine method, and r is the correlation coefficient. For the two methods to correspond the slope of this line should be very nearly one, the intercept should be zero and the r should be very close to one. The r value of 0.989 indicates a highly linear relationship between the two methods and the intercept of -3.7 ppm SO_2, although poor, is sufficiently close to zero to be acceptable. However, the slope of 1.67 indicates that the purge method will give results which are almost 70% higher than those obtained by titration. The origin of this deviation can be seen in the comparison of "free" and total SO_2. One can predict that in a natural product such as cherries the amount of "bound" SO_2 should be approximately the same in all 140 samples tested. This would imply that the linear regression equation comparing "free" and total SO_2 (TI) would have a slope of one and intercept equal to the negative of the average "bound" SO_2 of all the samples. The equation obtained using the purge method,

$$FP = 0.940\ TI - 4.53, \quad r = 0.993,$$

has a high degree of linearity ($r = 0.993$) and a slope of very nearly one (only 6% below expectation). Also, the 4.5 ppm average "bound" SO_2 seems acceptable. However, the equation obtained with data from the iodine titration method,

$$FI = 0.557\ TI - 0.347, \quad r = .992,$$

has a slope which is almost 50% below expectation and an intercept which implies a "bound" SO_2 of less than 0.4 ppm at the origin. What is more disturbing is that the "bound" SO_2 as defined by the iodine titration method increases with increasing total SO_2!

To further support this interpretation of the differences between the two methods for the analysis of "free" SO_2, a single uniform extract of dehydrated cherries which was less than 5 ppm SO_2 was divided into several identical fractions and different amounts of SO_2 were added to each one. Certainly the amount of SO_2 binding material in each of these should be the same and as increasing amounts of SO_2 was added to successive samples the "free" SO_2 should remain zero until all the SO_2 binding material has been consumed. Then the concentrations of the "free" SO_2 should increase parallel to the increase in the amount of SO_2 added. Thus, at all times would the difference between the total SO_2 added and the "free" SO_2 determined be equal to the "bound" SO_2 present in the

sample. This is an experimental description of what has been generally accepted as the essential concept of "free", "bound" and total SO_2. Figure 4.83 shows a plot of the amount of SO_2 added versus the amount of "free" SO_2 found using both methods of analysis. Here again the curve for the purge-colorimetric procedure yields data which are essentially parallel to the line for the total amount of SO_2 added (above about 30 ppm), whereas the iodine titration method yields a curve which is neither very linear nor even parallel to the total SO_2 added. It should also be noted that even the purge procedure does not give theoretical results below 30 ppm SO_2.

Similar results were obtained with dehydrated green bell peppers as can be seen in the set of linear regression equations below.

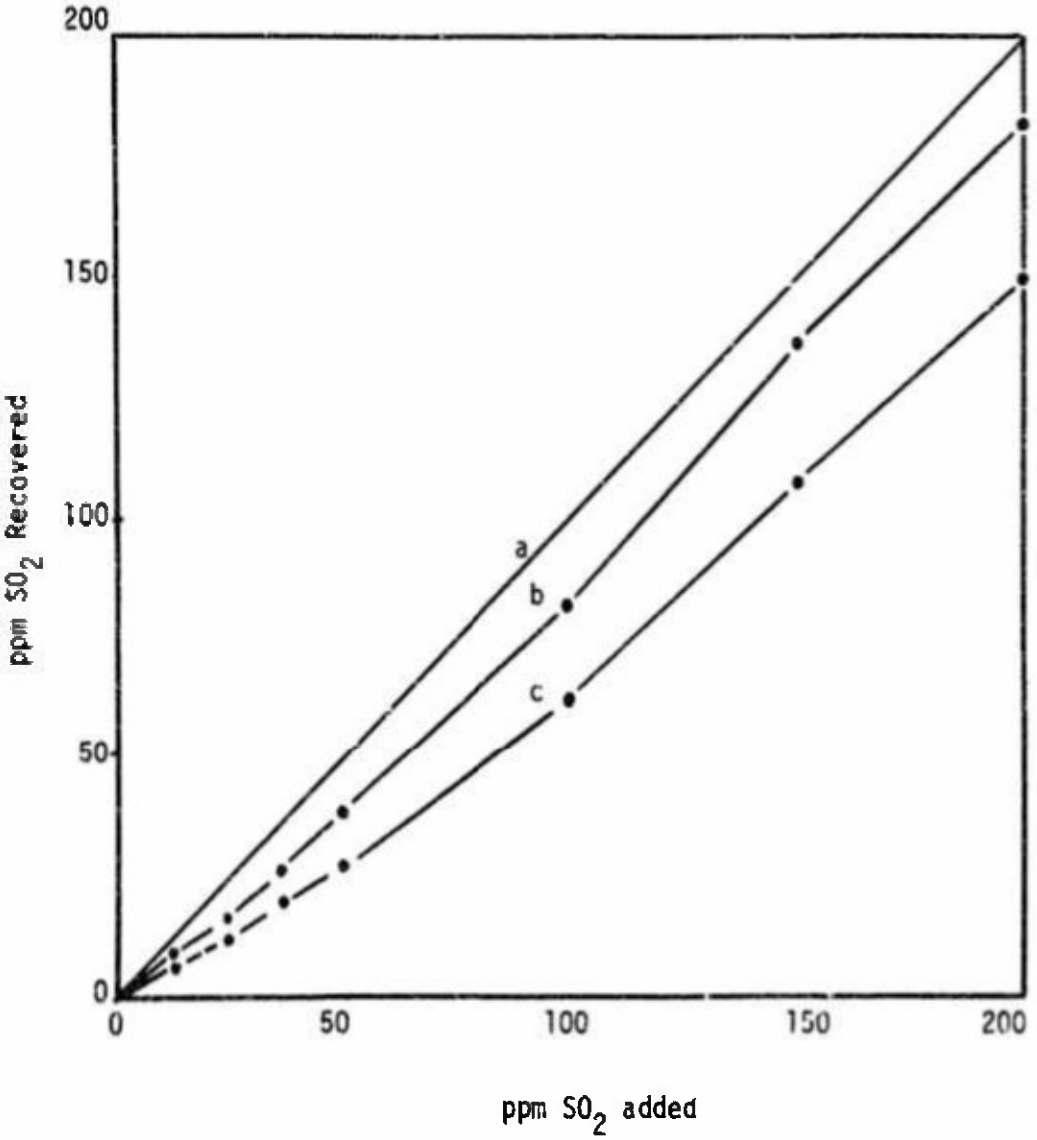
$$FP = 1.080\ FI - 12.2, \quad r = 0.997$$

$$FP = 1.012\ TI - 42.0, \quad r = 0.991$$

$$FI = 0.931\ TI - 25.8, \quad r = 0.988$$

Here again the intercepts in the last two equations indicate that the "bound" SO_2 as determined by the iodine titration method is significantly less (26 ppm) than that obtained from the purge-colorimetric method (42 ppm).

Figure 4.83 - A plot of the amount of SO_2 added to a cherry filtrate vs the amount of SO_2 recovered using two methods of analysis



a) theoretical total
b) free SO_2 by purge-colorimetric procedure
c) free SO_2 by iodine titration

4.9 CONCLUSIONS AND RECOMMENDATIONS

In spite of the fact that the work reported here indicates some improvements in the use of direct iodine titration for the determination of "free SO_2", the inconsistencies resulting from its application to dehydrated cherries shed some considerable doubt on its reliability. However, the purge colorimetric procedure seems to be not only reproducible but consistent with the present concepts of "free" and "bound" SO_2 both in model systems and natural products.

When acetaldhyde is the SO_2 binding substance in a solution, the direct iodine titration method is consistent with the theory of "free" SO_2. However, there obviously are SO_2 binding substances in cherries and to some extent peppers which interact with the iodine titration to produce data inconsistent with a simple concept of "free" and "bound" SO_2. This in itself would not be sufficient reason for the abandonment of iodine titrations for the determination of "free" SO_2. It could as justifiably be concluded that the presently accepted concept of "free" SO_2 requires revision. However, the fact that the purge-colorimetric method is theoretically consistent implies that the direct iodometric titration of "free" SO_2 in certain natural products may yield meaningless results.

The single most important recommendation that can be made for the direct iodometric titration of "free" SO_2 is to insure that the pH of the sample is in the range of 1 to 2 before titration. The table below is provided to allow a direct comparison between the two methods examined in this study.

Method	Direct iodine titration	Purge colorimetric
Simplicity	very simple	very simple
Reproducibility	± 3%	± 5%
Cost of equipment	$200 to $500	$1,000 to 1,500
Time and effort	10-15 samples/hr	10-15 samples/hr
Compatibility w/theory	poor	good

The advantages of the purge-colorimetric procedure over direct iodine titration are reliability, freedom from interferences due to pigments, and greater sensitivity. The only advantage of the iodine titration method is its low initial cost for equipment.

APPENDIX

CONTENTS:

4A.1	Glossary	58
4A.2	Descriptive terms for hedonic scale	59
4A.3	Complete tabulated and summarized data	60
4A.4	Diagrams and photographs of equipment	123
4A.5	Samples of dried products provided to NLABS	131
4A.6	Disclaimer on trade names of equipment	132
4A.7	Selected bibliography	133
4A.8	Acknowledgements	135

4A.1 GLOSSARY OF CODES, ABBREVIATIONS, AND TERMS.

Modes of dehydration:

AD = air-dried

AV = air/vacuum-dried - partially air-dried and then completed by vacuum-drying

FD = freeze-dried

Storage milieu:

	under N_2	with desiccant	temperature
A	x		- 35°F
AA	x	x	- 35°F
B	x		100°F
C	x	x	100°F
D		x	100°F

Av. = average = arithmetic mean

a = Hunter color (difference meter parameters for redness or, if negative, for blueness (or less directly, greenness)

L = Hunter parameter for brightness or reflectance

na = data not available (missing)

\- = no experimental data, or not applicable

NT = no (SO_2) treatment

w/d.= packaged with desiccant

wo/d. = packaged without desiccant

W.R. = weight reduction, or moisture removed in drying

bulk density = the weight of a given volume of particulate material

bulk volume = the volume occupied by a given (drained) weight of particulate material

4A.2 DESCRIPTIVE TERMS CORRESPONDING TO TEN-POINT HEDONIC SCALE as used in subjective evaluation of dried cherries, 1971

	EXTERIOR COLOR		INTERIOR COLOR
10	excellent	10	bright yellow, including pit cavity
9	very good	9	mostly bright yellow
8	good, sl. bleached	8	yellow, w/brown pit cavity
7	good, sl. dark or brown	7	yellow, sl. brown
6	dark red, some brown	6	mostly light brown
5	dark red w/brown or black	5	mod. yellow-brown
4	mostly brown, some red	4	intense yellow-brown
3	brown	3	mostly brown
2	brown-black, mostly black	2	dark brown
1	black	1	black

	TEXTURE (RELATIVE DRYNESS)		FLAVOR OR ODOR
10	crisp	10	excellent, cherry-like
9	mostly crisp	9	good, normal cherry, no ox.
8	nearly crisp; hard, not quite crisp	8	good, some cherry, no ox.
7	tough, not hard	7	faint cherry
6	sl. soft but still tough	6	neutral
5	mod. soft	5	off-flavor, not ox.
4		4	sl. oxidized
3	soft and sticky	3	moderately oxidized
2			
1	very soft and moist	1	pronounced oxidation

4A. 3 COMPLETE SUMMARY OF EXPERIMENTAL DATA IN TABULAR FORM

Table No.	Title
4A.3.01	Summary of experimental variables during SO_2 treatment and dehydration: Air-dried cherries.
4A.3.02	Residual SO_2 (free and total) in cherries during air-drying.
	Evaluation of Air-dried Cherries:
4A.3.03	Headspace Oxygen, %
4A.3.04	Hunter *a* (Redness)
4A.3.05	Hunter *L* (Brightness)
4A.3.06	Moisture, %
4A.3.07	Free SO_2 residual after six-month's storage
4A.3.08	Free (purged) SO_2 residual after six-month's storage
4A.3.09	Total SO_2 residual after six-month's storage
4A.3.10	Recovery, %
4A.3.11	Bulk volume, ml/g
4A.3.12	Texture (Instron), kg
4A.3.13	Exterior color (subjective)
4A.3.14	Flavor or odor (subjective)
4A.3.15	Relative dryness (subjective)
4A.3.16	Summary of experimental variables during SO_2 treatment and dehydration: Air/vacuum-dried cherries.
4A.3.17	Residual SO_2 (free and total) in cherries during air/vacuum-drying.
	Evaluation of Air/vacuum-dried Cherries
4A.3.18	Headspace Oxygen, %

4A.3.19 Hunter a (Redness)

4A.3.20 Hunter L (Brightness)

4A.3.21 Moisture, %

4A.3.22 Free SO_2 residual after six-month's storage

4A.3.23 Free (purged) SO_2 residual after six-month's storage

4A.3.24 Total SO_2 residual after six-month's storage

4A.3.25 Recovery, %

4A.3.26 Bulk volume, ml/g

4A.3.27 Texture (Instron), kg

4A.3.28 Exterior, color (subjective)

4A.3.29 Flavor or odor (subjective)

4A.3.30 Relative dryness (subjective)

4A.3.31 Summary of experimental variables during SO_2 treatment and dehydration: Freeze-dried[2] cherries.

4A.3.32 Residual SO_2 (free and total) in cherries during freeze-drying.

Evaluation of Freeze-dried Cherries:

4A.3.33 Headspace Oxygen, %

4A.3.34 Hunter a (Redness)

4A.3.35 Hunter L (Brightness)

4A.3.36 Moisture, %

4A.3.37 Free SO_2 residual after six-month's storage

4A.3.38 Free (purged) SO_2 residual after six-month's storage

4A.3.39 Total SO_2 residual after six-month's storage

4A.3.40 Recovery, %

4A.3.41 Bulk volume, ml/g.

4A.3.42 Texture (Instron), kg

4A.3.43 Exterior color (subjective)

4A.3.44 Interior color (subjective)

4A.3.45 Flavor or odor (subjective)

4A.3.46 Relative Dryness (subjective)

4A.3.47 Summary of experimental variables during SO_2 treatment and dehydration: Air-dried and Air/vacuum-dried green bell peppers (1971 pack).

Evaluation of Air-dried and Air/vacuum-dried Green Bell Peppers:

4A.3.48 SO_2 residual before and after storage, and bulk density

4A.3.49 Color measurement after six-month's storage

4A.3.50 Ratings of color and odor after six-month's storage

4A.3.51 Summary of experimental variables during SO_2 treatment and dehydration: Vacuum-dried and freeze-dried Green Bell Peppers (1971 pack).

Evaluation of Vacuum-dried and Freeze-dried Green Bell Peppers:

4A.3.52 SO_2 residual before storage, bulk density, and O_2 in container after storage.

4A.3.53 SO_2 residuals after six-month's storage.

4A.3.54 Color measurement after six-month's storage

4A.3.55 Ratings of color and odor after six-month's storage

4A.3.56 Evaluation of dried green bell peppers after six-month's storage at 100°F (1970 pack)

4A.3.57	Evaluation of dried apples before storage (1970 pack)
4A.3.58	Dehydrated apple dices, air-dried and air/vacuum-dried (1971 pack)

TABLE 4A.3.01 SUMMARY OF EXPERIMENTAL VARIABLES DURING SO_2 TREATMENT AND DEHYRATION AIR-ORIED CHERRIES, LOTS A001-22:

Code		SO_2 TREATMENT (Nominal ppm or %)		SO_2 TREATMENT (Actual ppm or %)		DEHYDRATION			
		pre-drying	mid-drying	pre-drying	mid-drying	Lot size, Kg.	Wt. Reduction, % after 60 min.	final	Drying time, min.
A001	[a]A	2,000	-	1,760	-	4.56	46.7	81.6	250
02	-	NT		-	-	5.56	35.8	82.2	527
3	A	4,000	-	3,610	-	7.42	42.0	83.0	420
4	A	10,000	-	8,080	-	7.31	45.1	83.3	420
5	A	4,000	4,000	2,990	2,650	7.44	62.2	84.6	360
6		-	4,000	-	2,800	8.22	57.1	83.2	360
7	B	4%	2%	3.7%	1.8%	7.11	59.3	83.0	480
8		-	2%	-	1.7%	8.89	55.2	82.1	480
9		NT		-	-	8.89	50.0	82.6	480
10	A	4,000	-	3,070	-	7.23	64.2	83.5	250
11	A	10,000	-	8,560	-	7.32	62.5	83.2	250
12	B	4%	2%	3.7%	1.9%	5.89	57.2	82.9	570
13		-	2%	-	1.8%	8.15	53.0	81.4	570
14	A	4,000	4,000	3,200	2,850	8.30	60.0	85.3	450
15		-	4,000	-	2,750	8.93	55.6	83.8	450
16		NT		-	-	8.78	60.0	82.9	360
17		-	7,000	-	5,630	8.58	58.1	83.3	360
18		-	2,000	-	1,950	7.96	59.4	84.3	417
19		-	4%	-	3.6%	8.08	58.6	84.2	417
20		-	7,000	-	6,700	6.30	62.6	84.7	350
21		-	10,000	-	10,260	6.19	57.1	83.9	360
22		-	3%	-	2.7%	18.65	61.1	81.2	260

a) before (B) or after (A) pitting

TABLE 4A.3 02 SUMMARY OF EXPERIMENTAL VARIABLES OURING SO_2 TREATMENT AND OEHYORATION
RESIDUAL SO_2 (free & total) IN CHERRIES OURING AIR-ORYING

Code		SO_2 TREATMENT Nominal ppm or % pre-drying	mid-drying	RESIDUAL SO_2, ppm Upon SO_2 Treatment during drying: Before drying free	free (purge)	total	Before sulfiting free	free (purge)	total	After sulfiting free	free (purge)	total	After drying free	free (purge)	total
AD01	A	2,000	-	48	na	95	-	-	-	-	-	-	4	6	9
2	-	NT		-	-	-	-	-	-	-	-	-	-	-	-
3	A	4,000	-	154	179	225	-	-	-	-	-	-	18	25	29
4	A	10,000	-	270	328	357	-	-	-	-	-	-	42	68	78
5	A	4,000	4,000	96	98	182	-	-	-	62	98	113	21	35	42
6	-	-	4,000	-	-	-	-	-	-	20	37	34	11	8	11
7	B	4%	2%	19	12	28				113	190	197	63	122	125
8	-	-	2%	-	-	-	-	-	-	137	222	224	76	128	162
9	-	NT		-	-	-	-	-	-	-	-	-	-	-	-
10	A	4,000	-	112	160	173	-	-	-	-	-	-	9	15	23
11	A	10,000	-	245	340	308	-	-	-	-	-	-	52	121	120
12	B	4%	2%	11	11	19	0	4	4	123	224	196	62	137	129
13		-	2%	-	-	-	-	-	-	128	214	199	71	156	132
14	A	4,000	4,000	119	206	185	38	80	71	58	103	101	18	42	36
15		-	4,000	-	-	-	-	-	-	13	29	23	4	11	5
16		NT		-	-	-	-	-	-	-	-	-	(4	-	7)
17		-	7,000	-	-	-	-	-	-	43	81	63	20	39	30
18		-	2,000	-	-	-	-	-	-	7	16	6	2	6	5
19		-	4%	-	-	-	-	-	-	269	452	380	122	321	238
20		-	7,000	-	-	-	-	-	-	42	92	65	23	30	35
21		-	10,000	-	-	-	-	-	-	69	73	113	50	88	84
22		-	3%	-	-	-	-	-	-	158	292	247	110	241	203

TABLE 4A 3.03 SUMMARY - EVALUATION OF AIR-ORIED CHERRIES - HEADSPACE OXYGEN, %

SO_2 TREATMENT	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D
	AO														
None	02	-	0.00	0.00	0.26	09					16	0.00	0.00	0.00	0.00
Dip (after pitting only)															
2,000 ppm	01	0.09	0.00	0.00	11.66	-					-				
4,000	03	0.56	0.00	0.00	0.00	10	0.00	0.00	0.00	12.29	-				
10,000	04	0.21	0.00	0.00	0.06	11	0.00	0.00	0.00	6.11	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	0.12	0.11	0.57	8.52	-				
NT/4,000	06	0.66	0.25	0.69	0.61	15	0.00	0.00	0.00	3.02	-				
NT/7,000	-					17	0.10	0.00	0.00	0.00	20				
NT/10,000	-					-					21				
4,000/4,000	05	0.08	0.00	0.00	4.00	14	0.00	0.00	0.07	10.39	-				
Gas (before pit & mid dry):															
NT/2%	08	0.00	0.00	0.00	0.00	13	0.76	0.15	0.09	8.11	-				
NT/3%	-					-					22	0.16	0.00	0.00	2.34
NT/4%	-					-					19	-	-	0.00	0.12
4%/2%	07	0.00	0.00	0.00	5.92	12	1.49	0.13	0.39	17.89	-				

TABLE 4A 3 04 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - HUNTER COLOR, a (Redness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	02	-				09	5.1	-1.1	-1.4	-1.0	16	6.8			
Oip (after pitting only):															
2,000 ppm	01	7.8	-1.5	-0.8	-1.9	-									
4,000	03	13.2				10	6.0	-1.9	-2.1	-1.9	-				
10,000	04	14.3	-2.1	-2.3	- 2.1	11	8.2	-1.8	-1.8	-1.7	-				
Dip (after pit & mid-dry):															
NT/2000	-					18	8.4	-1.4	-1.6	-1.9	-				
Nt/4,000	06	8.4	-1.2	-2.0	-1.5	15	7.3				-				
NT/7,000	-					17	8.7	-1.5	-1.5	-1.7	20	10.0	-1.0	-1.0	-1.4
NT/10,000	-					-					21	11.9	-1.7	-1.6	-1.6
4,000/4,000	05	11.0				14	10.4	-1.7	-0.6	-1.2	-				
Gas (before pit & mid-dry):															
NT/2%	08	11.2				13	11.7	-1.4	-1.7	-1.3	-				
NT/3%	-					-					22	13.3	-2.0	-1.8	-2.2
NT/4%	-					-					19	14.7	-1.4	-1.8	-1.6
4%/2%	07	9.9				12	10.6	-2.1	-1.0	-0.7	-				

TABLE 4A.3.05 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - HUNTER COLOR, L(Brightness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	A0														
None	02	-				09	16.8	14.3	14.4	15.0	16	18.1			
Dip (after pitting only):															
2,000 ppm	01	17.0	14.9	15.0	15.2	-					-				
4,000	03	20.2				10	17.1	14.9	14.6	15.1	-				
10,000	04	21.4	15.7	15.7	15.2	11	18.5	16.1	15.9	16.1	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	17.7	14.8	14.9	15.2	-				
NT/4,000	06	17.4	14.8	14.8	14.8	15	17.7				-				
NT/7,000	-					17	19.2	16.1	16.1	16.4	20	18.3	14.7	14.7	14.9
NT/10,000	-					-					21	19.4	15.8	14.9	15.2
4,000/4,000	05	19.2				14	18.5	14.8	15.9	15.3	-				
Gas (before pit & mid-dry):															
NT/2%	08	19.5				13	18.3	14.3	14.6	14.9	-				
NT/3%	-					-					22	21.0	14.6	14.6	14.3
NT/4%	-					-					19	23.1	14.9	14.4	14.1
4%/2%	07	18.4				12	18.2	14.5	15.5	15.8	-				

TABLE 4A.3.06 SUMMARY - EVALUATION OF AIR-ORIED CHERRIES - MOISTURE, %

SO_2 TREATMENT	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D
	AO														
None	02	21.38				09	13.29	16.23	14.46	11.61	16	20.40			
Dip (after pitting only):															
2,000 ppm	01	19.04	20.73	14.79	14.29	-									
4,000	03	26.72				10	15.54	12.28	14.35	15.21	-				
10,000	04	25.20	29.38	24.73	23.93	11	14.37				-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	14.47	18.07	13.87	12.83	-				
NT/4,000	06	20.10	23.54	20.70	20.83	15	17.45				-				
NT/7,000	-					17	19.12				20	18.76	21.13	17.97	18.14
NT/10,000	-					-					21	21.05	22.89	20.22	20.70
4,000/4,000	05	17.00				14	11.98	14.62	8.64	8.44	-				
Gas (before pit & mid-dry):															
NT/2%	08	20.69				13	16.87	19.76	15.36	15.00	-				
NT/3%	-					-					22	19.24	21.84	18.24	18.85
NT/4%	-					-					19	20.57	22.90	20.34	20.58
4%/2%	07	16.73				12	13.57	17.02	9.90	9.57	-				

TABLE 4A.3.07 SUMMARY - EVALUATION OF AIR-ORIED CHERRIES - FREE SO_2 RESIDUAL AFTER SIX MONTH'S STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	A0														
None	02	4.6*	-	-	-	09	12.2	2.3	0.0	0.0	16	3.8	-	-	-
Oip (after pitting only):															
2,000 ppm	01	7.6	3.0	0.8	0.0	-					-				
4,000	03	12.9	-	-	-	10	7.6	2.3	2.3	1.5	-				
10,000	04	38.0	3.8	0.0	0.0	11	44.1	-	-	-	-				
Oip (after pit & mid-dry):															
NT/2,000	-					18	6.1	1.5	3.8	0.0	-				
NT/4,000	06	6.1	0.0	0.0	0.0	15	6.1	-	-	-	-				
NT/7,000	-					17	23.6	-	-	-	20	177.1	0.0	0.0	0.0
NT/10,000	-					-					21	44.1	3.0	3.0	5.3
4,000/4,000	05	19.0	-	-	-	14	23.6	0.0	3.0	2.3	-				
Gas (before pit & mid-dry):															
NT/2%	08	77.5	-	-	-	13	77.5	3.8	0.0	2.3					
NT/3%	-					-					22	136.8	3.8	0.0	3.8
NT/4%	-					-					19	150.5	0.0	0.8	0.0
4%/2%	07	55.5	-	-	-	12	62.3	0.0	0.0	0.0	-				

* Sample not tested for SO_2

TABLE 4A.3.08 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - FREE (purged) SO_2 RESIDUAL AFTER SIX-MONTH'S STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	02	0.2*	-	-	-	09	0.0	0.0	0.1	0.0	16	0.9	-	-	-
Dip (after pitting only):															
2,000 ppm	01	5.6	0.1	0.1	0.0	-					-				
4,000	03	25.5	-	-	-	10	14.6	0.7	0.2	0.1	-				
10,000	04	57.1	0.3	0.0	0.2	11	87.3	-	-	-	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	5.9	0.1	0.1	0.3	-				
NT/4,000	06	10.3	0.1	0.1	0.1	15	12.0	-	-	-	-				
NT/7,000	-					17	35.5	-	-	-	20	306.9	0.0	0.0	0.0
NT/10,000	-					-					21	75.7	0.0	0.0	0.1
4,000/4,000	D5	33.6	-	-	-	14	36.9	0.0	0.0	0.5	-				
Gas (before pit & mid-dry):															
NT/2%	08	134.3	-	-	-	13	131.8	0.0	0.0	0.0	-				
NT/3%	-					-					22	218.6	0.0	0.1	0.2
NT/4%	-					-					19	279.8	0.1	0.4	0.5
4%/2%	07	103.6	-	-	-	12	114.5	0.0	0.0	0.0	-				

* mean sample not tested for SO_2

TABLE 4A.3.09 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - TOTAL SO_2 RESIDUAL AFTER SIX-MONTH's STORAGE

SO_2 TREATMENT	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D
	A0														
None	02	0.0*	-	-	-	09	21.3	3.8	11.4	7.6	16	3.8	-	-	-
Dip (after pitting only):															
2,000 ppm	01	15.2	0.8	0.8	0.0	-					-				
4,000	03	20.5	-	-	-	10	29.6	8.4	6.1	1.5	-				
10,000	04	78.3	3.0	3.8	0.0	11	107.9	-	-	-	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	5.3	2.3	2.3	4.6	-				
NT/4,000	06	6.1	0.0	0.0	0.0	15	6.8	-	-	-	-				
NT/7,000	-					17	35.7	-	-	-	20	311.6	3.8	3.8	6.1
NT/10,000	-					-					21	86.6	6.1	6.1	4.6
4,000/4,000	05	41.8	-	-	-	14	39.5	2.3	0.8	1.6	-				
Gas (before pit & mid-dry):															
NT/2%	08	140.6	-	-	-	13	151.2	4.6	11.4	6.1	-				
NT/3%	-					-					22	241.7	3.8	5.3	7.6
NT/4%	-					-					19	288.8	3.8	6.8	0.8
4%/2%	07	115.5	-	-	-	12	117.8	7.6	6.1	5.3	-				

* - means not tested for SO_2

TABLE 4A.3.10 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - RECOVERY, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	02	39.5*	33.3	34.7	35.4	09					16	38.3			
Oip (after pitting only):															
2,000 ppm	01					-					-				
4,000	03	39.3				10					-				
10,000	04					11	39.5				-				
Dip (after pit & mid-dry):															
NT/2,000	-					18					-				
NT/4,000	06					15	35.6				-				
NT/7,000	-					17	35.7				20				
NT/10,000	-					-					21				
4,000/4,000	05	38.0				14					-				
Gas (before pit & mid-dry):															
NT/2%	08	36.9				13					-				
NT/3%	-					-					22				
NT/4%	-					-					19				
4%/2%	07	36.6				12					-				

* Rehydration times: A002 (A): 18 hours; All others: 16 hours.

TABLE 4A.3.11 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - BULK VOLUME, ml/g

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	A0														
None	02	1.58*	1.82	1.92	1.76	09					16	1.61			
Dip (after pitting only):															
2,000 ppm	01					-					-				
4,000	03	1.73				10					-				
10,000	04					11	1.62				-				
Dip (after pit & mid dry):															
NT/2,000	-					18					-				
NT/4,000	06					15	1.55				-				
NT/7,000	-					17	1.59				20				
NT/10,000	-					-					21				
4,000/4,000	05	1.66				14					-				
Gas (before pit & mid dry):															
NT/2%	08	1.55				13					-				
NT/3%	-					-					22				
NT/4%	-					-					19				
4%/2%	07	1.58				12					-				

* Rehydration times: A002 (A) = 18 hours; All rest = 16 hours

TABLE 4A.3 12 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - TEXTURE (INSTRON), Kg

SO_2 TREATMENT	CODE	Sample A	B	C	D	CODE	Sample A	B	C	D	M CODE	Sample A	B	C	D
	AO														
None	02	91*	152	188	79	09					16				
Dip (after pitting only):															
2,000 ppm	01					-					-				
4,000	03	120				10					-				
10,000	04					11	73				-				
Dip (after pit & mid-dry):															
NT/2,000	-					18					-				
NT/4,000	06					15	76				-				
NT/7,000	-					17	74				20				
NT/10,000	-					-					21				
4,000/4,000	05	128				14					-				
Gas (before pit & mid-dry):															
NT/2%	08	80				13					-				
NT/3%	-					-					22				
NT/4%	-					-					19				
4%/2%	07	98				12					-				

* Rehydration times: A002 (A) = 18 hours; all rest = 16 hours.

TABLE 4A.3.13 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - EXTERIOR COLOR (Subjective)

SO_2 TREATMENT	Code	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	02					09	6	2	2	2	16	8	1	1	1
Dip (after pitting only):															
2,000 ppm	01	7	1	2	2	-					-				
4,000	02	9	1	1	1	10	7	2	2	2	-				
10,000	03	8	1	1	1	11	9	1	1	1	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	10	1	1	1	-				
NT/4,000	06	7	1	1	1	15	9	1	1	1	-				
NT/7,000	-					17	8	1	1	1	20	7	1	1	1
NT/10,000	-					-					21	7	1	1	1
4,000/4,000	05	9	1	2	2	14	10	1	3	2	-				
Gas (before pit & mid-dry):															
NT/2%	08	9	1	1	1	13	10	1	1	1	-				
NT/3%	-					-					22	8	1	2	1
NT/4%	-					-					19	7	1	1	1
4%/2%	07	9	1	1	1	12	10	1	3	3	-				

TABLE 4A.3 14 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - FLAVOR OR ODOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	02					09	8				16				
Dip (after pitting only):															
2,000 ppm	01	10	-	-	-	-					-				
4,000	03					10	8	-	-	-	-				
10,000	04	8	-	-	-	11					-				
Dip (after pit & mid-dry):															
NT/2,000	-					18					-				
NT/4,000	06	9	-	-	-	15					-				
NT/7,000	-					17					20				
NT/10,000	-					-					21				
4,000/4,000	05					14					-				
Gas (before pit & mid-dry):															
NT/2%	08					13	9	-	-	-	-				
NT/3%	-					-					22				
NT/4%	-					-					19				
4%/2%	07					12	9	-	-	6	-				

TABLE 4A.3.15 SUMMARY - EVALUATION OF AIR-DRIED CHERRIES - RELATIVE DRYNESS (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AD														
None	D2					09	6	4	8	8	16	7	-	6	6
Dip (after pitting only):															
2,000 ppm	D1	4	4	4	7	-					-				
4,000	03	8	-	-	-	10	6	7	7	7	-				
10,000	D4	1	1	4	4	11	7	-	7	7	-				
Dip (after pit & mid-dry):															
NT/2,000	-					18	6	3	3	3	-				
NT/4,000	D6	4	4	4	6	15	7	-	7	7	-				
NT/7,000	-					17	7	-	6	6	20	5	3	5	5
NT/10,000	-					-					21	3	1	3	3
4,000/4,000	D5	8	-	-	-	14	5	5	8	7	-				
Gas (before pit & mid-dry):															
NT/2%	D7	7	-	-	-	13	4	-	6	6	-				
NT/3%	-					-					22	5	2	4	4
NT/4%	-					-					19	4	3	5	5
4%/2%	07	7	-	-	-	12	6	4	8	8	-				

TABLE 4A.3.16 SUMMARY OF EXPERIMENTAL VARIABLES DURING SO_2 TREATMENT AND DEHYDRATION AIR/VACUUM-DRIED CHERRIES, LOTS AV01-21:

Code	SO_2 TREATMENT Nominal ppm or % pre-drying	SO_2 TREATMENT Nominal ppm or % mid-drying	SO_2 TREATMENT Actual ppm or % pre-drying	SO_2 TREATMENT Actual ppm or % mid-drying	Lot size, Kg,	Wt. Reduction, % after	Wt. Reduction, % final	Drying time, min.
AV01	2,000	-	na	-	7.60	59	82.6	490
2	4,000	4,000	na	na	4.50	69	86.8	540
3	4,000	-	na	-	4.57	69	85.1	540
4	10,000	-	6,710	-	5.01	61	85.5	450
5	NT		-	-	5.71	65	86.4	670
6	10,000	10,000	9,200	5,320	7.88	66	86.4	600
7	-	10,000	-	5,060	8.30	62	85.4	600
8	4%	2%	4.0%	1.8%	7.23	65	83.3	595
9	-	2%	-	1.6%	8.39	64	84.3	595
10	4,000	4,000	3,500	3,040	7.39	69	86.2	560
11	-	4,000	-	3,020	7.97	66	83.9	560
12	4%	2%	3.5%	1.9%	5.56	66	85.7	600
13	-	2%	-	1.8%	8.04	62	86.9	600
14	NT		-	-	7.52	64	87.0	595
15	-	7,000	-	5,300	7.63	62	86.8	595
16	-	2,000	-	1,430	7.55	63	87.4	540
17	-	4,000	-	2,750	7.84	61	87.6	540
18	-	4%	-	3.6%	8.44	65	88.0	540
19	-	7,000	-	5,920	8.45	63	88.3	540
20	-	3%	-	2.8%	18.26	66	87.0	570
21	-	4%	-	3.5%	9.83	64	85.8	570

TABLE 4A.3.17 SUMMARY OF EXPERIMENTAL VARIABLES OURING SO_2 TREATMENT ANO OEHYORATION RESIOUAL SO_2 (free and total) IN CHERRIES OURING AIR/VACUUM ORYING

Code	SO_2 TREATMENT		RESIDUAL SO_2, ppm Upon SO_2 Treatment during Drying												
			Before drying			Before sulfiting			After sulfiting			After drying			
	Nominal ppm or % pre-drying	mid-drying	free	free (purge)	total	free	free (purge)	total	free	free (purge)	total	free	free (purge)	total	
AV01	2,000	-	na			-	-	-	-	-	-	na			
2	4,000	[illegible]	na			na			na			na			
3	4,000	-				-	-	-	-	-	-	na			
4	10,000	-	na			-	-	-	-	-		na			
5	NT		-	-	-	-	-	-	-	-	-	-	-	-	
6	10,000	10,000	na			na			na			na			
7	-	10,000	-	-	-	-	-	-	na			na			
8	4%	2%	11	18	24	8	4	8	110	191	188	40	79	88	
9	-	2%	-	-	-	-	-	-	120	168	192	50	95	91	
10	4,000	4,000	115	157	165	31	48	53	43	69	78	27	49	51	
11	-	4,000	-	-	-	-	-	-	15	20	23	8	12	8	
12	4%	2%	15	21	23	2	5	1	140	264	238	52	104	104	
13	-	2%	-	-	-	-	-	-	140	282	201	57	124	103	
14	NT		-	-	-	-	-	-	-	-	-	(2	0	4)	
15	-	7,000	-	-	-	-	-	-	na			na			
16	-	2,000	-	-	-	-	-	-	2	na	2	1	na	1	
17	-	4,000	-	-	-	-	-	-	13	21	20	8	13	13	
18	-	4%	-	-	-	-	-	-	270	384	361	59	161	156	
19	-	7,000	-	-	-	-	-	-	59	92	81	30	44	73	
20	-	3%	-	-	-	-	-	-	184	306	310	81	163	128	
21	-	4%	-	-	-	-	-	-	220	424	323	85	178	128	

TABLE 4A.3.18 SUMMARY OF AIR/VACUUM-DRIED CHERRIES - HEADSPACE OXYGEN, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05					14	0.50	0.18	0.00	18.51					
Dip (after pitting only):															
2,000 ppm	01	0.00	0.00	0.06	17.69	-									
4,000	03	0.09	0.02	0.95	20.00	-									
10,000	04	0.23	0.10	0.00	19.75	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	0.40	0.22	0.21	18.38	-				
NT/4,000	-					11	0.84	0.40	0.32	18.88	17	0.18	0.00	0.00	18.42
NT/7,000	06	0.76	0.12	0.00	12.90	15	1.47	0.58	0.31	18.71	19	2.06	0.00	0.00	19 04
10,000/10,000															
NT/10,000	07	0.21	0.00	0.00	2.15	-					-				
4,000/4,000	02	0.00	0.00	0.00	20.08	10	0.19	0.62	2.77	19.19	-				
Gas (before pit & mid-dry):															
NT/2%	09	0.34	0.18	0.00	19.08	13	5.45	0.13	0.00	18.97	-				
NT/3%	-					-					20	0.38	0.14	0.28	19.53
NT/4%	-					18	0.52	0.00	0.28	19.22	21	0.23	0.00	0.00	19.15
4%/2%	08	0.19	0.21	0.00	19.49	12	-	-	0.02	19.55	-				

TABLE 4A.3.19 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - HUNTER COLOR, a (Redness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	11.2	1.9	6.1	10.0	14	11.5	3.7	6.5	8.0					
Oip (after pitting only):															
2,000 ppm	01	12.4	-0.9	10.3	2.9	-									
4,000	03	13.8	1.9	9.3	8.7	-									
10,000	04	9.6	1.6	5.5	6.2	-									
Oip (after pit & mid-dry):															
NT/2,000	-					16	11.6	3.2	8.2	9.0	-				
NT/4,000	-					11	10.1	2.3	5.9	7.4	17	14.4	3.2	8.7	8.6
NT/7,000	-					15	12.2	3.8	8.4	8.5	19	15.9	2.3	9.8	10.9
10,000/10,000	06	15.7	-0.9	1.0	0.8	-					-				
NT/10,000	07	9.7	-1.6	-0.0	-0.7										
4,000/4,000	02	13.2	1.5	9.8	10.8	10	13.2	3.5	7.1	8.6	-				
Gas (before pit & mid-dry):															
NT/2%	09	13.8	4.6	7.5	8.7	13	15.8	3.6	8.5	8.4	-				
NT/3%	-					-					20				
NT/4%	-					18	17.1	3.4	10.0	10.7	21				
4%/2%	08	13.3	5.2	6.9	7.8	12	15.4	3.7	9.1	11.7	-				

TABLE 4A.3.20 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - HUNTER COLOR L (Brightness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	19.6	17.5	18.4	19.6	14	19.6	18.4	19.0	18.9					
Dip (after pitting only):															
2,000 ppm	01	19.0	14.1	20.0	17.1	-									
4,000	03	19.8	16.6	19.1	18.6	-									
10,000	04	18.9	16.8	18.9	18.2	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	20.5	19.1	19.8	20.4	-				
NT/4,000	-					11	19.4	17.4	19.0	19.7	17	20.4	18.0	19.7	19.0
NT/7,000	-					15	20.6	18.5	20.2	20.2	19	21.6	17.2	20.6	20.6
10,000/10,000	06	22.4	15.6	17.7	17.6										
NT/10,000	07	19.4	15.7	16.6	15.5	-					-				
4,000/4,000	02	20.3	17.3	19.6	19.6	10	20.4	18.5	19.3	19.3					
Gas (before pit & mid-dry):															
NT/2%	09	20.2	18.5	18.4	18.9	13	23.3	19.8	20.8	21.0	-				
NT/3%	-					-					20	24.3	19.1	21.3	21.3
NT/4%	-					18	24.7	18.6	20.2	20.8	21	26.4	19.5	22.8	21.8
4%/2%	08	19.6	17.8	18.3	18.6	12	22.4	18.2	20.3	22.8	-				

TABLE 4A.3.21 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - MOISTURE, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	4.80	6.00	2.22	1.65	14	3.58	5.57	1.12	1.31					
Dip (after pitting only):															
2,000 ppm	01	7.13	8.22	7.88	2.56	-									
4,000	03	5.34	3.36	1.61	2.37	-									
10,000	04	8.13	6.29	1.39	2.14	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	4.96	7.51	0.88	1.78	-				
NT/4,000	-					11	5.17	7.72	1.68	1.47	17	5.38	7.11	1.96	1.66
NT/7,000	-					15	3.80	5.21	1.06	1.90	19	6.70	8.77	2.78	2.96
10,000/10,000	06	3.45	5.59	10.00	9.62	-					-				
NT/10,000	07	13.60	17.69	13.90	14.42										
4,000/4,000	02	8.69	7.70	2.43	2.96	10	5.40	6.12	2.56	3.12	-				
Gas (before pit & mid-dry):															
NT/2%	09	2.54	6.54	1.66	0.99	13	2.65	5.07	1.80	2.68	-				
NT/3%	-					-					20	5.91	8.99	3.35	3.74
NT/4%	-					18	5.27	8.20	1.18	1.77	21	4.15	5.78	0.02	1.89
4%/2%	08	3.44	4.07	1.72	1.04	12	9.75	10.15	5.00	5.75	-				

TABLE 4A.3.22 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - FREE SO_2 RESIDUALS AFTER SIX-MONTH'S STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	3.8	0.0	2.3	0.0	14	2.3	1.5	0.8	0.0					
Oip (after pitting only):															
2,000 ppm	01	22.8	0.0	0.0	3.0	-									
4,000	03	23.6	0.0	0.8	2.3	-									
10,000	04	22.0	5.3	3.8	4.6	-									
Oip (after pit & mid-dry):															
NT/2,000	-					16	9.9	1.5	3.8	4.6	-				
NT/4,000	-					11	11.4	2.3	3.0	3.0	17	6.1	0.0	0.0	0.0
NT/7,000	-					15	29.6	0.0	9.9	0.0	19	19.8	0.0	1.5	2.3
10,000/10,000	06	84.4	2.3	2.3	0.0	-					-				
NT/10,000	07	28.9	0.0	0.0	0.0	-					-				
4,000/4,000	02	20.5	0.0	0.0	1.5	10	41.0	0.0	3.8	5.3	-				
Gas (before pit and mid-dry):															
NT/2%	09	57.0	0.0	2.3	3.0	13	59.3	0.0	3.8	3.0	-				
NT/3%	-					-					20	93.5	1.5	0.8	3.0
NT/4%	-					18	102.6	5.3	5.3	3.8	21	117.8	3.8	7.6	11.4
4%/2%	08	40.3	0.0	2.3	1.5	12	61.6	6.8	6.1	11.4	-				

TABLE 4A.3.23 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - FREE (purged) SO_2 RESIDUAL AFTER SIX-MONTH'S STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	0.1	0.1	0.0	0.1	14	0.2	0.2	0.2	0.2					
Dip (after pitting only):															
2,000 ppm	01	17.4	0.0	0.0	0.1	-									
4,000	03	23.1	0.0	0.1	1.0	-									
10,000	04	34.1	0.1	0.2	0.5	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	5.6	0.0	0.0	0.0	-				
NT/4,000	-					11	18.6	0.7	0.8	0.8	17	15.6	0.2	0.2	0.3
NT/7,000	-					15	35.1	0.9	0.7	0.9	19	38.1	0.0	0.1	0.1
10,000/10,000	06	121.8	0.8	0.3	0.1	-					-				
NT/10,000	07	46.1	0.8	0.8	0.3										
4,000/4,000	02	43.0	0.4	0.5	1.7	10	56.1	0.8	1.0	1.2	-				
Gas (before pit & mid-dry):															
NT/2%	09	84.6	0.5	2.9	4.0	13	111.2	0.8	4.1	7.1	-				
NT/3%	-					-					20	148.1	0.3	3.7	5.1
NT/4%	-					18	149.8	0.0	4.6	3.1	21	162.7	0.7	5.3	7.5
4%/2%	08	74.6	0.4	5.0	5.0	12	101.8	0.2	2.6	3.8	-				

TABLE 4A.3.24 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - TOTAL SO_2 RESIDUAL AFTER SIX-MONTHS STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	2.3	2.3	0.0	4.6	14	2.3	0.0	3.0	5.3					
Dip (after pitting only):															
2,000 ppm	01	22.8	2.3	3.0	1.5	-									
4,000	03	28.9	3.0	3.8	6.8	-									
10,000	04	36.5	7.6	5.3	4.6	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	11.4	3.0	6.8	7.6	-				
NT/4,000	-					11	13.7	8.4	2.3	3.8	17	7.6	5.3	4.6	6.1
NT/7,000	-					15	39.5	3.0	9.1	6.1	19	36.6	0.0	6.1	9.9
10,000/10,000	06	134.5	9.9	2.3	7.6	-					-				
NT/10,000	07	41.0	0.0	7.6	5.3										
4,000/4,000	02	30.4	1.5	5.3	7.6	10	55.5	3.8	7.6	3.8	-				
Gas (before pit & middry):															
NT/2%	09	92.7	9.9	19.9	12.2	13	118.6	5.3	8.4	10.6	-				
NT/3%	-					-					20	149.7	0.8	19.0	19.0
NT/4%	-					18	159.6	9.9	22.8	19.8	21	210.5	3.0	20.5	25.1
4%/2%	08	80.6	6.8	12.9	19.0	12	123.9	9.1	13.7	15.2	-				

TABLE 4A.3.25 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - RECOVERY, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05					14	32.4	-	33.7	34.2					
Dip (after pitting only):		(1)													
2,000 ppm	01	42.3	41.6	49.2	45.2	-									
4,000	03	41.9	40.7	42.2	42.8	-									
10,000	04	39.6	39.6	41.3	41.0	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	33.9	32.4	31.2	34.4	-				
NT/4,000	-					11	41.4	41.4	43.1	43.8	17	31.9	-	33.2	33.2
NT/7,000	-					15	34.3	34.2	35.2	34.8	19	29.4	-	32.3	31.8
10,000/10,000	06	35.8	33.9	35.2	35.4										
NT/10,000	07	35.0	32.1	33.3	34.0	-					-				
4,000/4,000	02	37.9	-	39.7	39.2	10	36.6	36.6	38.0	38.2	-				
Gas (before pit & mid-dry):															
NT/2%	09	39.1	-	40.0	40.2	13	32.1	33.0	34.5	34.1	-				
NT/3%	-					-					20	33.7	33.8	34.5	34.8
NT/4%	-					18	31.1	-	31.8	33.0	21	35.2	37.9	38.6	38.1
4%/2%	08	42.3	-	43.6	43.4	12	-	-	37.8	38.2	-				

(1) Rehydration times: AV01 (A) = 1 hour; AV16 (A) = 17 hours; all rest = 4 hours.

TABLE 4A 3 26 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - BULK VOLUME, m^3/g

SO, TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	D5					14	1.98	-	1.91	2D.3					
Oip (after pitting only):															
2,000 ppm	01	1.73*	2.07	1.67	1.85	-									
4,000	03	1.71	1.8D	1.82	1.74	-									
10,000	04	1.76	1.71	1.78	1.75	-									
Oip (after pit & mid-dry):															
NT/2,000	-					16	1.73*	2.02	1.94	1.85	-				
NT/4,000	-					11	1.87	1.97	1.84	1.76	17	2.07	-	1.94	1.99
NT/7,000	-					15	1.85	2.01	1.95	1.97	19	1.86	-	1.93	1.96
10,000/10,000	C6	1 78	1.82	1.75	1.79										
NT/10,000	07	1.72	2.00	1.99	1.85	-					-				
4,000/4,000	D2	1.72	-	1.64	1.70	10	2.01	1.96	1.84	1.83	-				
Gas (before pit & mid dry):															
NT/2%	09	1.93	-	1.94	1.82	13	1.85	1.75	1.83	1.79	-				
NT/3%	-					-					20	1.86	1.79	1.81	1.84
NT/4%	-					18	1.91	-	1.86	1.70	21	1.99	1.95	1.81	1.94
4%/2%	08	2.00	-	1.89	1.95	12	-	-	1.82	1.75	-				

* Rehydration times: AV01 (A) = 1 hour; AV16 (A) = 17 hours; all rest = 4 hours

TABLE 4A.3 27 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - TEXTURE (INSTRON) Kg

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05					14	50	-	52	50					
Oip (after pitting only):															
2,000 ppm	01	102	135	83	96	-									
4,000	03	92	93	86	94	-									
10,000	04	91	96	93	84	-									
Oip (after pit & mid-dry):															
NT/2,000	-					16	52	60	52	50	-				
NT/4,000	-					11	68	72	60	55	17	64	-	56	57
NT/7,000	-					15	60	58	53	54	19	64	-	57	59
10,000/10,000	D6	76	127	78	95	-					-				
NT/10,000	07	84	135	106	74										
4,000/4,000	D2	104	-	88	83	10	70	77	63	68	-				
Gas (before pit & mid-dry):															
NT/2%	09	53	-	50	49	13	54	50	54	55	-				
NT/3%	-					-					20	58	64	62	64
NT/4%	-					18	52	-	58	57	21	54	62	54	58
4%/2%	08	62	-	58	58	12	-	-	66	62	-				

. E 4A 3 28 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - EXTERIOR COLOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	7	2	5	6	14	7	3	5	6					
Dip (after pitting only):															
2,000 ppm	01	10	2	4	7	-									
4,000	03	10	2	7	7	-									
10,000	04	8	2	5	6	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	10	2	5	5	-				
NT/4,000	-					11	8	2	5	6	17	9	2	6	6
NT/7,000	-					15	8	3	6	6	19	8	2	6	7
10,000/10,000	06	8	1	2	2										
NT/10,000	07	7	1	1	1	-					-				
4,000/4,000	02	7	1	5	5	10	10	3	6	7	-				
Gas (before pit & mid-dry):															
NT/2%	09	9	3	5	6	13	8	2	4	5	-				
NT/3%	-					-					20	8	2	5	6
NT/4%	-					18	8	2	6	6	21	8	2	5	6
4%/2%	08	10	4	5	6	12	8	3	5	6	-				

TABLE 4A.3 29 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - FLAVOR OR ODOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	9	2	4	4	14									
Dip (after pitting only):															
2,000 ppm	01	9	2	3	5	-									
4,000	03	9	2	6	5	-									
10,000	04	9	2	4	4	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	8	-	5	-	-				
NT/4,000	-					11	7	-	-	-	17				
NT/7,000	-					15	8	-	5	-	19				
10,000/10,000	06	9	-	-	-										
NT/10,000	07	9	-	-	-	-					-				
4,000/4,000	02					10	9	-	7	5	-				
Gas (before pit & mid-dry):															
NT/2%	09					13					-				
NT/3%	-					-					20				
NT/4%	-					18					21				
4%/2%	08					12					-				

TABLE 4A-3 30 SUMMARY - EVALUATION OF AIR/VACUUM-DRIED CHERRIES - RELATIVE DRYNESS (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	AV														
None	05	10	6	10	10	14	9	7	10	10					
Dip (after pitting only):															
2,000 ppm	01	6	5	7	10	-									
4,000	03	6	7	10	10	-									
10,000	04	9	7	10	10	-									
Dip (after pit & mid-dry):															
NT/2,000	-					16	10	6	10	10	-				
NT/4,000	-					11	9	6	10	10	17	8	6	10	10
NT/7,000	-					15	8	8	10	10	19	8	6	10	10
10,000/10,000	06	6	4	8	8	-					-				
NT/10,000	07	5	2	4	4										
4,000/4,000	02	7	7	10	10	10	10	8	10	10	-				
Gas (before pit & mid-dry):															
NT/2%	09	9	7	10	10	13	10	7	10	10	-				
NT/3%	-					-					20	9	5	10	10
NT/4%	-					18	8	6	10	10	21	10	7	10	10
4%/2%	08	9	7	10	10	12	9	6	10	10	-				

TABLE 4A 3.31 SUMMARY OF EXPERIMENTAL VARIABLES DURING SO_2 TREATMENT AND DEHYDRATION FREEZE-DRIED CHERRIES, LOTS FD01-20:

Code		SO_2 TREATMENT Nominal ppm or % pre-drying	during drying	SO_2 TREATMENT Actual ppm or % pre-drying	during drying	DEHYDRATION Lot size, Kg.	Wt. Reduction,% Final	Drying time hr.
FD01	[a]B	NT	-	-	-	5.40	83.8	44
2	A	2,000	-	na	-	7.91	84.2	41
3	A	2,000	-	na	-	7.32	84.7	41
4	B	5,000	-	3,550	-	3.40	84.3	41
5	A	5,000	-	3,920	-	3.25	85.1	41
6		-	[b]C 1%	-	1.0%	4.45	84.1	41
8		-	C 2%	-	1.6%	5.90	84.0	20
10		NT		-	-	3.06	86.8	65
11	B	2,000	-	1,630	-	3.43	86.7	65
12	A	2,000	-	1,820	-	3.21	87.9	65
14		-	I 4%	-	3.9%	5.45	85.2	20
16		NT		-	-	3.07	85.8	39
17	B	5,000	-	3,930	-	2.17	87.8	39
18	A	5,000	-	3,870	-	2.16	88.2	39
20	A	5,000	-	5,100	-	17.30	87.4	na

a) before (B) or after (A) pitting

b) drying completed (C) or incomplete (I) when treated with gaseous SO_2.

TABLE 4A 3 32 SUMMARY OF EXPERIMENTAL VARIABLES DURING SO_2 TREATMENT AND DEHYDRATION - RESIDUAL SO_2 (free & total) IN CHERRIES DURING FREEZE-DRYING

Code		SO_2 TREATMENT Nominal ppm or % pre-drying	during drying	RESIDUAL SO_2, ppm Before drying free	free (purge)	total	After drying free	free (purge)	total
FD01		NT		-	-	-	-	-	-
2	B	2,000	-	na			na		
3	A	2,000	-	na			na		
4	B	5,000	-	11	na	25	5	na	10
5	A	5,000	-	106	na	190	47	59	86
6		-	F 1%	4	na	10	1	1	5
8		-	F 4%	na			5	4	11
10		NT		-	-	-	-	-	-
11	B	2,000	-	0	3	9	2	1	4
12	A	2,000	-	27	93	95	30	32	38
14		-	M 4%	na			4	7	13
16		NT		-	-	-	-	-	-
17	B	5,000	-	11	14	19	6	7	11
18	A	5,000	-	192	263	280	46	86	87
20	A	5,000	-	217	345	257	53	89	91

TABLE 4A 3 33 SUMMARY - EVALUATION OF FREEZE-ORIED CHERRIES - HEADSPACE OXYGEN, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	0.35	0.04	0.02	18.75	10	0.00	0.00	0.00	19.55	16	0.64	0.48	0.15	19.12
Dip (before Pitting):															
2,000 ppm	02	0.30	-	0.00	18.78	11	0.14	0.09	0.00	19.39	-				
5,000	04	0.35	0.22	0.00	19.54	17	0.28	0.12	1.57	19.59	-				
Dip (after pitting):															
2,000	03	0.86	-	0.02	18.86	12	0.12	0.00	0.00	19.62					
5,000	05	0.28	0.19	0.00	19.10	18	0.22	0.25	0.00	19.41	20	0.04	0.00	0.00	19.72
Gas (after drying):															
1%	06	0.37	0.14	0.00	19.12	-					-				
4%	08	0.03	0.00	0.00	19.39	-					-				
Gas (mid-drying):															
4%	-					14	0.14	0.03	0.00	19.15					

TABLE 4A.3 34 SUMMARY - EVALUATION OF FREEZE-ORIED CHERRIES - HUNTER COLOR a (Redness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	COOE	Storage A	B	C	D	COOE	Storage A	B	C	D
	FD														
None	01	14.3	10.8	11.1	11.4	10	16.8	11.2	11.5	12.4	16	12.9	8.0	8.0	9.2
Oip (before pitting):															
2,000 ppm	02	15.6	10.6	9.9	12.4	11	13.3	10.1	11.7	13.1	-				
5,000	04	13.8	9.0	9.1	9.8	17	13.9	7.8	9.7	11.2	-				
Dip (after pitting):															
2,000	03	17.6	-	12.5	12.7	12	16.9	11.4	12.0	14.0					
5,000	05	16.5	10.5	11.6	10.8	18	16.9	10.1	11.4	13.0	20	19.2	11.2	13.7	13.5
Gas (after drying):															
1%	06	12.7	8.6	9.8	9.8	-					-				
4%	08	12.4	5.7	8.6	11.9	-					-				
Gas (mid-drying):															
4%	-					14	14.4	4.7	13.0	14.5	-				

TABLE 4A.3 35 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - HUNTER COLOR, L (Brightness)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
None	FO OT	21.2	20.6	21.0	20.6	10	21.8	20.8	21.0	20.5	16	23.1	21.8	22.3	22.8
Dip (before pitting):															
2,000 ppm	02	22.8	26.8	20.9	21.6	11	23.8	22.8	21.2	22.0	-				
5,000	04	21.1	19.0	19.4	20.2	17	23.2	21.0	20.8	24.3	-				
Dip (after pitting):															
2,000	03	23.9	-	21.3	22.0	12	25.0	23.7	23.2	24.1					
5,000	05	22.7	20.3	21.1	19.8	18	26.3	22.1	21.9	22.6	20	27.4	23.1	22.1	22.6
Gas (after drying):															
1%	06	21.7	20.9	20.6	20.9	-					-				
4%	08	20.4	18.8	19.6	20.9	-					-				
Gas (mid-drying):															
4%	-					14	21.0	18.2	22.7	21.4					

TABLE 4A.3 36 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - MOISTURE, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	2.26	3.47	3.39	4.92	10	3.19	4.47	2.11	2.43	16	2.17	4.47	0.52	0.77
Dip (before pitting):															
2,000 ppm	02	3.71	4.49	4.53	3.29	11	3.14	4.38	0.33	0.89	-				
5,000	04	2.47	4.04	0.27	0.39	17	3.26	4.60	1.07	1.00	-				
Dip (after pitting):															
2,000	03	1.97	4.27	1.70	4.86	12	2.58	2.70	0.24	1.19					
5,000	05	3.47	3.60	0.92	1.27	18	1.10	1.17	0.91	1.53	20	4.49	5.23	1.73	1.73
Gas (after drying):															
1%	06	4.12	4.58	1.80	7.81	-					-				
4%	08	6.72	7.56	3.21	3.22	-					-				
Gas (mid-drying):															
4%	-					14	6.45	7.43	2.76	2.80	-				

TABLE 4A 3 37 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - FREE SO_2 RESIDUAL AFTER SIX-MONTH's STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	3.0	2.3	0.8	1.5	10	1.5	0.8	0.8	0.0	16	3.8	3.0	2.3	0.8
Dip (before pitting):															
2,000 ppm	02	28.9	2.3	0.8	2.3	11	0.8	0.0	1.5	1.5	-				
5,000	04	11.4	0.0	0.8	6.1	17	8.4	0.8	7.6	0.0	-				
Dip (after pitting):															
2,000	03	22.0	0.0	2.3	2.3	12	22.8	0.0	3.0	3.0					
5,000	05	50.9	1.5	7.6	6.1	18	57.0	0.0	12.9	13.7	20	52.4	0.0	13.7	16.0
Gas (after drying):															
1%	06	7.6	3.8	0.0	4.6	-					-				
4%	08	0.0	0.0	0.0	0.0	-					-				
Gas (mid-drying):															
4%	-					14	12.2	3.8	3.0	0.0	-				

TABLE 4A 3 38 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - FREE (purged) SO_2 RESIDUALS AFTER SIX-MONTHS STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	0.0	0.1	0.1	0.0	10	0.4	0.3	0.3	0.3	16	0.0	0.0	0.0	0.0
Dip (before pitting):															
2,000 ppm	02	38.7	0.1	0.1	0.1	11	0.0	0.0	0.0	0.0	-				
5,000	04	7.7	0.5	0.6	0.4	17	0.3	0.0	0.0	0.2	-				
Dip (after pitting):															
2,000	03	42.7	0.6	1.9	0.6	12	26.4	0.0	1.2	3.0					
5,000	05	82.7	1.3	9.1	8.3	18	61.8	0.3	8.7	3.0	20	93.5	0.2	11.0	11.1
Gas (after drying):															
1%	06	0.1	0.0	0.1	0.1	-					-				
4%	08	3.1	0.0	0.1	0.1	-					-				
Gas (mid-drying):															
4%	-					14	8.4	0.2	0.1	0.0	-				

TABLE 4A 3 22 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - TOTAL SO_2 RESIDUAL AFTER SIX-MONTH'S STORAGE

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FO														
None	01	5.8	3.0	3.0	3.8	10	6.1	3.0	1.5	6.8	16	4.6	4.6	0.0	4.6
Dip (before pitting):															
2,000 ppm	02	42.6	2.3	3.8	8.4	11	8.4	0.0	2.3	9.1	-				
5,000	04	12.2	6.1	6.1	3.8	17	7.6	5.3	8.4	6.8	-				
Dip (after pitting):															
2,000	03	41.8	5.3	6.1	4.6	12	36.5	6.8	2.3	6.8					
5,000	05	83.6	6.8	7.6	8.4	18	85.9	0.8	17.5	20.5	20	85.9	3.0	21.3	14.4
Gas (after drying):															
1%	06	22.8	2.3	0.0	3.0	-					-				
4%	08	6.1	0.0	3.0	1.5	-					-				
Gas (mid-drying):															
4%	-					14	13.7	9.1	6.1	9.1	-				

TABLE 4A 3 40 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - RECOVERY, %

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FO														
None	D1	43.1	47.6	44.9	46.0	10	36.4	38.0	38.8	39.1	16	39.6	40.2	41.6	42.0
Dip (before pitting):															
2,000 ppm	02	46.1	47.1	46.8	48.7	11	37.4*	42.0	41.4	43.0	-				
5,000	04	42.2	43.3	44.6	43.6	17	35.1	34.5	36.6	35.1	-				
Dip (after pitting):															
2,000	03	37.4	-	52.3	52.2	12	39.2	40.1	39.6	41.3					
5,000	05	40.5	43.2	44.1	43.5	18	33.5	34.6	35.4	37.1	20	34.3	35.5	37.3	37.3
Gas (after drying):															
1%	06	44.5	42.6	45.3	44.8	-					-				
4%	08	43.2	41.9	47.4	47.4	-					-				
Gas (mid-drying):															
4%	-					14	39.1	37.9	42.3	41.3	-				

* Rehydration times: FD11(A) - 1 hours; all rest = 1-1/2 hour

TABLE 4A.3.41 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - BULK VOLUME, ml/g

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	D1	2.26	2.11	2.46	2.18	10	2.07	2.08	1.84	2.06	1	2.35	2.35	2.32	2.17
Oip (before pitting):															
2,000 ppm	02	2.26	2.21	2.23	2.16	11	2.19*	2.04	2.07	2.06	-				
5,000	04	2.27	2.46	2.32	2.30	17	2.32	2.32	2.14	2.46	-				
Oip (after pitting):															
2,000	03	2.26	-	2.38	2.33	12	2.22	1.98	2 22	2.00	-				
5,000	05	2.35	2.28	2.23	2.26	18	2.27	2.35	2.22	2.17	20	2.21	2.27	2.30	2.16
Gas (after drying):															
1%	06	2.36	2.14	2.19	2.27	-					-				
4%	08	2.22	2.29	2.06	2.09	-					-				
Gas (mid-drying):															
4%	-					14	2.12	2.27	1.98	1.94	-				

* Rehydration times: FD11(A) = 1 hour; All rest = 1-1/2 hour

TABLE 4A.3 42 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - TEXTURE (INSTRON), Kg

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	81	85	89	78	10	52	55	40	48	16				
Dip (before pitting):															
2,000 ppm	02	-	76	76	75	11	-	-	-	-	-				
5,000	04	62	77	72	63	17	-	-	-	-	-				
Dip (after pitting):															
2,000	03	108	-	96	98	12	-	-	-	-					
5,000	05	63	64	56	68	18	66	52	61	-	20	35	42	38	37
Gas (after drying):															
1%	06	72	68	66	70	-					-				
4%	08	68	(62)	58	48	-					-				
Gas (mid-drying):															
4%	-					14	43	53	37	34	-				

Rehydration time = 1-1/2 hour

TABLE 4A 3.43 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - EXTERIOR COLOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	10	5	5	6	10	9	3	6	6	16	7	2	4	5
Dip (before pitting):															
2,000 ppm	02	10	5	5	6	11	10	6	7	8	-				
5,000	04	10	4	6	6	17	10	4	7	6	-				
Dip (after pitting):															
2,000	03	9	-	7	7	12	10	5	7	8	-				
5,000	05	10	6	7	7	18	10	5	6	8	20	10	6	7	6
Gas (after drying):															
1%	06	9	4	6	6	-					-				
4%	08	10	5	5	5	-					-				
Gas (mid-drying):															
4%	-					14	10	4	6	6	-				

TABLE 4A.3.44 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - INTERIOR COLOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	O	CODE	Storage A	B	C	O	CODE	Storage A	B	C	O
	FO														
None	01	7	4	4	5	10	8	2	4	4	16				
Dip (before pitting):															
2,000 ppm	D2	9	5	5	5	11					-				
5,000	D4	8	5	5	6	17					-				
Dip (after pitting):															
2,000	03	9	-	6	5	12					-				
5,000	05	10	5	6	6	18					20	10	3	5	6
Gas (after drying):															
1%	06	9	3	3	4	-					-				
4%	08	9	2	2	2	-					-				
Gas (mid-drying):															
4%	-					14	9	2	2	2	-				

TABLE 4A.3 45 SUMMARY - EVALUATION OF FREEZE-ORIED CHERRIES - FLAVOR OR ODOR (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	-	2	2	4	10	7	1	2	2	16				
Oip (before pitting):															
2,000 ppm	02	10	7	5	5	11					-				
5,000	04	-	2	2	5	17					-				
Oip (after pitting):															
2,000	03	10	-	-	4	12									
5,000	05	10	2	3	5	18					20	9	2	5	5
Gas (after drying):															
1%	06	-	6	4	4	-					-				
4%	08	9	5	4	5	-					-				
Gas (mid-drying):															
4%	-					14	8	5	5	5	-				

TABLE 4A 3 46 SUMMARY - EVALUATION OF FREEZE-DRIED CHERRIES - RELATIVE DRYNESS (Subjective)

SO_2 TREATMENT	CODE	Storage A	B	C	D	COOE	Storage A	B	C	D	CODE	Storage A	B	C	D
	FD														
None	01	8	7	7	8	10	8	7	10	10	16	10	8	10	10
Dip (before pitting):															
2,000 ppm	02	10	7	7	9	11	10	9	10	10	-				
5,000	04	8	7	10	1D	1/	10	8	10	1D	-				
Dip (after pitting):															
2,000	03	9	-	10	9	12	10	8	10	10	-				
5,000	05	8	7	10	10	18	10	8	10	10	20	10	6	10	10
Gas (after drying):															
1%	06	1D	9	10	10	-					-				
4%	08	8	7	10	10	-					-				
Gas (mid-drying):															
4%	-					14	8	7	10	10	-				

TABLE 4A.3 47 SUMMARY OF EXPERIMENTAL VARIABLES OURING SO_2 TREATMENT ANO OEHYIRATION - AIR-DRIED AND AIR/VACUUM-ORIED GREEN BELL PEPPERS (1971 Pack).

Code	SO_2 TREATMENT				DEHYDRATION			
	Nominal ppm	Actual ppm	Dip time, min	Lot size, kg.	Weight Reduction, % air-dryer	Final	Drying time air-dryer min.	Drying time vacuum-dryer hr.
AD01	(H_2O only)	0	5	3.03	93.8	-	153	-
2	4000 (H_2SO_3)	3730	5	2.88	93.7	-	165	-
3	4000 ($NaHSO_3$)	4240	5	3.06	93.9	-	170	-
4	(H_2O only)	0	5	8.80	95.6	-	165	-
5	4000 $NaHSO_3$)	3940	5	8.88	95.5	-	165	-
AV01	NT	-	-	2.96	53.5	92.5	24	20
2	NT	-	-	3.15	63.9	92.5	32	21
3	NT	-	-	3.03	72.9	92.7	39	21
4	4000 ($NaHSO_3$)	4280	2	3.00	61.8	93.2	38	10
5	4% (SO_2)	3.0%	5	3.00	63.0	92.4	38	10
6	NT	-	-	2.93	50.7	92.1	20	21
7	NT	-	-	3.01	67.4	92.3	25	21
8	4% (SO_2)	3.0%	5	2.98	35.6	92.4	18	20
9	4% (SO_2)	3.0%	5	4.46	50.1	92.2	23	20

EVALUATION OF AIR-DRIED AND AIR/VACUUM-DRIED GREEN BELL PEPPERS (1971 Pack)

TABLE 4A 3 48 SO_2 RESIDUAL BEFORE AND AFTER STORAGE, AND BULK DENSITY

SO_2 Treatment	Code	SO_2 RESIDUAL, ppm								Bulk density kg/l.
		Before Storage		After storage (6 months @ 100°F)						
		free	total	total		free		free (purge)		
				a B	C	B	C	B	C	
None (control dip in H_2O)	AD01									
None " " " "	4	-	-	-	-	-	-	-	-	-
Dip, 4,000 ppm ($NaHSO_3$)	3	133	224	10	251	6	162	2	175	.177
" " " "	5	-	na	-	-	-	-	-	-	.194
Dip, 1,000 ppm (H_2SO_3)	2	70	74	8	80	4	51	0	41	-
	Av.	102	149	9	166	5	106	1	108	.186
None (W.R. = 50%)	AV01	-	-	-	-	-	-	-	-	.220
" " "	6	-	-	-	-	-	-	-	-	.212
" (W.R. = 60%)	2	-	-	-	-	-	-	-	-	.204
" " "	7	-	-	-	-	-	-	-	-	.223
" (W.R. = 70%	3	-	-	-	-	-	-	-	-	.243
Dip, 4,000 ppm ($NaHSO_3$ (W.R. = 60%)	4	299	309	0	373	0	295	2	319	.239
Gas, 4% SO_2 (W.R. = 40%)	8	277	342	4	477	2	279	0	362	.247
" " " (W.R. = 50%)	9	426	528	20	526	5	353	2	439	.260
" " " (W.R. = 60%)	5	266	353	11	403	0	394	0	308	.284
	Av.	317	383	9	445	2	355	1	357	.237

a) "B" storage packed unter nitrogen and without desiccant; "C" storage packed under nitrogen and with desiccant.

EVALUATION OF AIR-DRIED AND AIR/VACUUM-DRIED GREEN BELL PEPPERS (1971 Pack)

TABLE 4A.3.49 COLOR MEASUREMENT AFTER SIX-MONTH'S STORAGE UNDER VARIOUS CONDITIONS

SO_2 Treatment	Code	GREENNESS (Hunter a) -35°F wo/d. (A)	-35°F w/d. (AA)	100°F wo/d. (B)	100°F w/d. (C)	BRIGHTNESS (Hunter L) -35°F wo/d. (A)	-35°F w/d. (AA)	100°F wo/d. (B)	100°F w.d. (C)
None (control dip in H_2O)	A001	-5.1	-5.4	+1.9	-4.2	31.5	32.2	28.6	32.2
" " " "	4	5.6	5.5	0.8	4.6	33.8	32.6	29.9	32.2
Dip, 4,000 ppm ($NaHSO_3$)	3	7.1	6.9	0.4	6.7	31.1	31.6	29.0	31.6
" " " "	5	6.5	6.8	0.7	5.7	31.4	31.1	29.0	30.9
" " " (H_2SO_3)	2	2.0	3.0	2.3	2.0	28.4	30.2	27.6	29 6
	Av.	-5.5	-5.5	+1.2	-4.6	31.2	31.5	28.8	31.3
None (W.R. = 50%)	Av01	5.4	5.1	1.9	4.8	28.8	27.6	26.9	28.6
" " "	6	4.5	4.9	2.0	3.7	28.4	27.5	25.7	28.1
" (W.R. = 60%)	2	5.7	5.9	1.9	4.9	28.4	27.7	27.3	28.9
" " "	7	4.8	4.8	2.0	3.8	28.6	28.2	26.2	28.9
" (W.R. = 70%)	3	5.0	5.1	1.7	3.8	27.7	27.6	25.5	26.9
Dip, 4,000 ppm ($NaHSO_3$) (W.R. = 60%)	4	4.9	6.0	3.0	5.1	29.4	27.2	23.2	27.2
Gas, 4% SO_2 (W.R. = 40%)	8	3.8	4.1	2.6	4.0	27.6	27.6	24.5	26.3
" " " " = 50%)	9	4.1	4.0	2.1	3.8	27.5	27.2	24.6	28.1
" " " " = 60%)	5	3.7	3.9	2.6	3.1	27.5	27.4	24.2	28.1
	Av.	-4.7	-4.9	+2.0	-4.1	28.2	27.6	25.3	27.9

EVALUATION OF AIR-DRIED AND AIR/VACUUM-DRIED GREEN BELL PEPPERS (1971 Pack)

Table 4A 3.5D SUBJECTIVE RATINGS OF COLOR AND ODOR AFTER SIX-MONTH'S STORAGE

SO_2 Treatment	Code	[a]	COLOR				ODOR			
			-35°F		100°F		-35°F		100°F	
			wo/d. (A)	w/d. (AA)	wo/d. (B)	w/d. (C)	wo/d. (A)	w/d. (AA)	wo/d. (B)	w/d. (C)
None (control dip in H_2O)	A001		5	7	2	5	7	7	1	7
" " " " "	4		8	7	4	6	8	8	3	7
Dip, 4,000 ppm ($NaHSO_3$)	3		8	8	4	7	8	8	3	7
" " " "	5		8	8	4	8	7	8	3	7
Dip, 4,000 ppm (H_2SO_3)	2		4	4	2	4	7	7	3	7
	Av.		6.6	6.4	3.2	6.0	7.4	7.6	2.6	7.0
None (W.R. = 50%)	AV01		8	8	4	9	9	8	3	7
" " "	6		na	7	4	7	8	8	3	7
" (W.R. = 60%)	2		8	9	5	9	9	8	3	7
" (W.R. = 60%)	7		na	7	4	7	9	8	3	8
" (W.R. = 70%)	3		8	7	3	7	na	8	2	7
Dip, 4,000 ppm ($NaHSO_3$) (W.R. = 60%)	4		8	8	1	8	6	6	2	6
Gas, 4% SO_2 (W.R. = 40%)	8		9	8	2	8	7	7	4	7
" " " (W.R. = 50%)	9		na	7	4	8	7	7	4	7
" " " (W.R. = 60%)	4		9	5	2	7	7	7	2	5
	Av.		(8.3)	7.5	3.2	7.8	7.8	7.5	2.9	6.8

a) Storage code - see Glossary

TABLE 4A.3 51 SUMMARY OF EXPERIMENTAL VARIABLES OURING SO_2 TREATMENT ANO OEHYORATION VACUUM-ORIEO ANO FREEZE-ORIEO GREEN BELL PEPPERS (1971 Pack)

	SO_2 TREATMENT			OEHYORATION		
Code	Nominal ppm	Actual ppm	Oip time, min.	Lot size, kg	Weight reduction,%	Drying time hr.
VD01	(H_2O only)	0	5	2.90	94.0	21
2	(4000 ($NaHSO_3$)	3860	5	2.92	93.7	21
3	(H_2O only)	0	5	2.98	93.3	21
4	4000 ($NaHSC_3$)	4110	5	2.86	93.2	21
FD01	NT		-	2.91	93.1	30
2	4%(SO_2)	3.1%	5	2.92	93.1	30
3	1000 (H_2SO_3)	960	5	1.78	94.3	30
4	2000 ($NaHSO_3$)	2240	5	2.93	93.9	30
5	4000 ($NaHSO_3$)	4460	5	2.93	93.8	30
6	8000 ($NaHSO_3$)	9050	5	2.90	93.7	30
7	2000 ($NaHSO_3$)	1970	2	2.82	93.8	30
8	4000 ($NaHSO_3$)	3980	2	2.81	93.8	30
9	8000 ($NaHSO_3$)	7820	2	2.67	93.7	30
10	4000 ($NaHSO_3$)	4080	5	8.40	93.8	12

EVALUATION OF VACUUM-DRIED AND FREEZE-DRIED GREEN BELL PEPPERS (1971 Pack)

TABLE 4A 3 52 SO_2 RESIDUALS BEFORE STORAGE, BULK DENSITY, AND O_2 IN CONTAINER HEADSPACE AFTER STORAGE

SO_2 Treatment	Code	SO_2 residual before storage		Bulk density	Headspace O_2 %			
		Total	Free	kg/l.	A	AA	B	C
None (Control dip in H_2O)	V001	-	-		0	0	0	0
" " " " "	3	-	-		0	0	0	0
Dip, 4000 ppm ($NaHSO_3$)	2	na		.163	0	0	0	0
" " " "	4	243	160	.137	na	0	0	0
	Av.	-	-	.150	0	0	0	0
None	F001	-	-		na			
Dip, 2000 ppm/5 min ($NaHSO_3$)	4	186	198		2.0	1.4	0.5	0.9
" 4000 " " "	5	391	346	.0514	1.6	1.1	0	0.5
" 8000 " " "	6	733	665		1.1	0.8	0	0.2
Dip, 2000 ppm/2 min ($NaHSO_3$)	7	11	4		2.5	1.9	0.9	1.3
" 4000 " " "	8	289	243	0.0486	2.3	1.4	0.5	0.7
" 8000 " " "	9	635	559		1.6	1.1	0.1	0.5
Dip, 1000 ppm/5 min (H_2SO_3)	3	na			na			
Gas, 4% SO_2/5 min	2	56	39		0.8	0.6	0	0.1
	Av.	329	293	.0500	1.7	1.2	0.3	0.6

EVALUATION OF VACUUM-ORIED AND FREEZE-ORIED GREEN BELL PEPPERS (1971 Pack)

Table 4A.3 53 SO_2 RESIDUALS AFTER SIX-MONTH'S STORAGE UNDER VARIOUS CONDITIONS.

SO_2 Treatment	Code	SO_2 RESIDUAL, ppm											
		Total SO_2				Free SO_2				Free (Purge) SO_2			
		A	AA	B	C	A	AA	B	C	A	AA	B	C
None (control dip in H_2O)	V001	-	-	-	-	-	-	-	-	-	-	-	-
" " " " "	3	-	-	-	-	-	-	-	-	-	-	-	-
Dip, 4000 ppm ($NaHSO_3$)	2	na				na				na			
" " " "	4	na		84	452	na		35	401	na		22	372
	AV	-	-	-	-	-	-	-	-	-	-	-	-
None	F001	-	-	-	-	-	-	-	-	-	-	-	-
Dip, 2000 ppm/5 min ($NaHSO_3$)	4	262	258	78	247	241	239	43	215	229	227	34	216
" 4000 " " "	5	467	456	110	475	400	422	46	437	448	442	40	469
" 8000 " " "	6	956	1005	299	1000	911	973	123	930	985	972	187	985
Dip, 2000 ppm/2 min ($NaHSO_3$)	7	208	222	65	209	186	166	56	187	161	185	39	181
" 4000 " " "	8	367	409	144	429	344	361	82	375	308	317	71	362
" 8000 " " "	9	690	766	120	828	675	726	52	766	728	711	72	819
Dip, 1000 ppm/5 min (H_2SO_3)	3	na				na				na			
Gas, 4% SO_2/5 min	2	80	60	18	59	74	61	12	71	35	24	0	21
	AV.	433	455	119	464	404	421	59	425	413	411	63	436

EVALUATION OF VACUUM-DRIED AND FREEZE-DRIED GREEN BELL PEPPERS (1971 Pack)

TABLE 4A.3.54 COLOR MEASUREMENT AFTER SIX-MONTH's STORAGE UNDER VARIOUS CONDITIONS

SO_2 Treatment	Code	a	GREENNESS (Hunter a)[b] -35°F wo/d. (A)	-35°F w/d. (AA)	100°F wo/d. (B)	100°F w/d. (C)	BRIGHTNESS (Hunter L) -35°F wo/d. (A)	-35°F w/d. (AA)	100°F wo/d. (B)	100°F w/d. (C)
None (Control dip in H_2O)	VD01		-7.7	-7.8	-0.1	-7.4	35.4	34.6	32.7	34.8
" " " " "	3		8.4	8.5	4.1	8.4	35.0	34.5	34.7	36.7
Dip, 4000 ppm ($NaHSO_3$)	2		8.1	7.8	1.6	8.3	34.5	34.7	32.9	34.6
" " " "	4		8.3	8.2	4.8	8.7	32.6	31.5	33.5	33.0
	AV.		-8.1	-8.1	-2.7	-8.2	34.4	33.8	33.5	34.8
None	FD01		-10.6	-10.9	-3.6	-10.0	45.1	46.6	43.6	46.2
Dip, 2000 ppm/5 min ($NaHSO_3$)	4		10.3	10.7	7.3	11.6	48.9	49.8	48.8	52.1
" 4000 " " "	5		10.4	10.4	7.1	11.1	47.8	47.8	48.6	51.0
Dip 8000 " " "	6		11.1	10.7	8.1	11.2	49.4	48.3	48.9	48.0
Dip, 2000 ppm 2/min ($NaHSO_3$)	7		10.7	10.6	7.8	10.2	50.8	50.6	49.4	49.6
" 4000 " " "	8		10.6	10.8	8.0	10.0	48.8	49.3	49.7	49.9
" 8000 " " "	9		10.9	10.6	6.9	10.9	48.9	48.4	47.7	49.5
Dip, 1000 ppm/5 min (H_2SO_3)	3		9.7	9.7	2.4	7.8	45.4	46.0	46.4	44.6
Gas, 4% SO_2/5 min	2		10.8	11.0	2.3	9.7	45.3	48.4	42.5	46.6
	AV		-10.6	-10.6	-5.9	-10.3	47.8	48.4	47.3	48.4

a) storage code - see Glossary

b) negative values of a actually denote intensity of blue

EVALUATION OF VACUUM-ORIED AND FREEZE-ORIED GREEN BELL PEPPERS (1971 Pack)

TABLE 4A.3 55 SUBJECTIVE RATINGS OF COLOR AND ODOR AFTER SIX-MONTH'S STORAGE

SO_2 Treatment	Code	COLOR				ODOR			
		-35°F		100°F		35°F		100°F	
		wo/d. (A)	w/d. (AA)	wo/d. (B)	w/d. (C)	wo/d. (A)	w/d. (AA)	wo/d. (B)	w/d. (C)
None (control dip in H_2O)	V001	9	9	4	7	9	9	3	8
" " " " "	3	8	9	5	9	9	7	5	8
Dip, 4000 ppm ($NaHSO_3$)	2	10	10	4	7	7	7	3	8
" " " "	4	9	8	5	9	7	7	5	7
	AV	9 0	9.0	4.5	8.0	8.0	7.5	4.0	7.8
None	FD01	9	9	5	7	9	9	4	7
Dip 2000 ppm/5 min ($NaHSO_3$)	4	9	9	6	10	9	9	6	6
" 4000 " " "	5	9	9	6	7	9	9	3	6
" 8000 " " "	6	9	9	6	7	9	9	4	6
Dip, 2000 ppm/2 min($NaHSO_3$)	7	9	9	6	9	9	9	6	8
" 4000 " " "	8	9	9	6	9	9	9	6	8
" 8000 " " "	9	9	9	6	9	9	9	5	8
Dip, 1000 ppm/5 min(H_2SO_3)	3	9	9	4	7	9	9	4	7
Gas, 4% SO_2/5 min	2	9	9	4	7	9	9	5	7
	AV	9.0	9.0	6.6	8.0	9.0	9.0	4.8	7.0

TABLE 4A.3.56 EVALUATION OF DRIED GREEN BELL PEPPERS AFTER SIX MONTH'S STORAGE AT 100°F (1970 Pack).

Code (70N-)	Sulfite treatment level/time ppm/min	Sulfite treatment source chemical	Moisture, %	SO_2, ppm (residual)	Bulk density, kg/l.
P13 - FD07	2000/2	H_2SO_3	4.2	0	.048
P14 - F007	2000/4	H_2SO_3	4.7	22	.047
P15 - FD09	2000/8	H_2SO_3	4.0	14	.042
P21 - F013	4000/2	$NaHSO_3$	-	254	.050
P22 - F014	4000/4	$NaHSO_3$	-	254	.049
P23 - FD15	4000/8	$NaHSO_3$	-	309	.059
P49 - F020	None		-	14	-
P50 - FD21	2%/5 vacuum + SO_2		-	0	-
P42 - A002	none, dried @ 170°F		-	-	.174
P43 - AD03	none, dried @ 150°F		-	-	.173
P52 - A006	1000/5 H_2SO_3 (dried @ 170°F)		6.6	11	.158
P53 - AD07	2000/5 H_2SO_3		6.7	28	.165
P16 - VD05	None shelf @ 180°F		3.0	-	-
P54 - AV02	None air dried to 80% wt. reduction		4.0	-	.193
P55 - AV03	None	85%	5.1	-	.177
P56 - AV04	None	90%	4.5	-	.181

TABLE 4A.3.56 (Cont.).

Code (70N-)	Reflected Color (Hunter) L -35°F	L 100°F	a/b -35°F	a/b 100°F	Subjective Evaluation
F007	47.2	47.8	.61	.20	All samples slightly brown @ 100°F, but good color at lower storage temperatures
F008	46.9	47.3	.59	.14	
FD09	47.1	47.6	.58	.13	
F013	49.6	49.5	.67	.47	
FD14	49.7	49.9	.68	.46	
FD15	49.3	49.8	.68	.40	
F020	43.9	40.9	.64	.18	Both moderately brown with strong haylike odor
F021	44.8	41.1	.63	.18	
A002	32.2	25.8	.22	+.56	AD02 brownish-green and AD03 slightly brown @ -35°F but both AD02 and 03 dark brown @ 100°F
AD03	32.5	27.1	.30	+.52	
AD06	31.2	28.8	.22	.40	Both AD06 and 07 light brownish-green @ 100°F
AOD7	31.7	29.8	.25	.38	
VD05	31.1	29.9	.67	.02	very green with good pepper color @ -35°F, but light brownish-green @ 100°F
AVD2	31.1	28.7	.57	+.40	All of these too brown with hay-like odor @ 100°F but slightly more so with increasing proportion of air drying
AV03	32.4	29.3	.54	+.35	
AVD4	32.0	30.3	.50	+.32	

a) Hunter a/b values are all negative.

TABLE 4A.3.57 EVALUATION OF DRIED APPLES BEFORE STORAGE (1970 Pack).

Code (70N-)	Treatment: ppm SO_2 or % NaCl for/min	Cut of Apple	Weight Reduction,%	Bulk Density kg/l.	Subjective Evaluation
A15 - FD04	1% NaCl/3	dices	87.9	.0664	Almost no brown
A16 - F005	2% NaCl/3	dices	87.6	.0762	discoloration
A17 - F006	3% NaCl/3	dices	87.4	.0872	
A39 - FD13	1% NaCl/5	slices	87.8	.0643	Browning in near-
A40 - F014	2% NaCl/5	slices	87.9	.0621	core tissue.
A41 - FD15	3% NaCl/5	slices	87.1	.0711	
A18 - F007	1000 SO_2/2	dices	88.4	.0577	No obvious
A19 - F008	2000 SO_2/2	dices	88.5	.0578	differences in
A20 - FD09	3000 SO_2/2	dices	88.4	.0598	color or texture
A24 - FD10	1000 SO_2/3	slices	87.8	.0640	No obvious
A25 - F011	2000 SO_2/3	slices	87.7	.0601	differences.
A26 - F012	3000 SO_2/3	slices	87.9	.0609	
A12 - A004	H_2O only	dices	87.5	.215	Very brown.
A11 - AD03	1% NaCl/3	dices	88.3	.246	Only light brown.
A10 - A002	2% NaCl/3	dices	87.3	.261	Only light brown.
A13 - AD05	3% NaCl/3	dices	86.7	.278	Very light brown.
A30 - AD10	1% NaCl/5	slices	86.0	.166	Brown on surface.
A31 - AD11	2% NaCl/5	slices	86.0	.149	Brown in center.
A32 - AD12	3% NaCl/5	slices	86.4	.159	No brown centers.
A42 - AD13	1000 SO_2/2	dices	87.9	.213	Good color in all.
A43 - A014	2000 SO_2/2	dices	87.6	.235	SO_2 detectable in
A44 - AD15	3000 SO_2/2	dices	87.8	.234	AD15.
A21 - AD07	1000 SO_2/3	slices	86.1	.168	Some browning.
A22 - AD08	2000 SO_2/3	slices	85.9	.148	Only in fibers and
A23 - A009	3000 SO_2/3	slices	85.9	.149	centers. No browning
A07 - AV02	1000 SO_2/3[b]	dices	86/89[b]	.186	Slight brown tinge
A08 - AV03	1000 SO_2/3[c]	dices	80/89	.179	in all three.
A09 - AV04	1000 SO_2/3[c]	dices	56/89	.210	

a) salty flavor increasingly noticeable in treatments with NaCl from 1 to 3%.

b) SO_2 as H_2SO_3 instead of $NaHSO_3$ as in all previous lots.

c) Dices pretreated in 1% NaCl.

d) after air- and vacuum-drying, respectively.

TABLE 4A.3.58 DEHYDRATED APPLE DICES, AIR-DRIED AND AIR/VACUUM-DRIED (1971 Pack)

CODE (71NAP)	Cut, in.	SO_2 Treatment (Actual), ppm	Air-drying 1st Stage W.R. %	1st Stage Time min	2nd Stage W.R. %	2nd Stage Time min	Vacuum drying W.R. %	Vacuum drying time hr	Final Moisture,% air-dried	Final Moisture,% vacuum-dried	SO_2 ppm
AD09	3/8"	2970	88.3	140[a]	-	-	-	-	1.1	-	
AD10	3/8"	1520	83.8	47	89.6	35	-	-	2.7	-	
AV01(AD11)	3/8"	1560	66.9	26	86.2	20		7	20.8	1.96	
AV02(AD15)	3/8"	3150	66.6	28	85.4	23		7	24.9	3.04	
AV03(A020)	3/8"	1340	65.1	35	86.0	28		7	18.7	4.14	
AV04(AD46)	1/2"	1520	65.1	34	86.0	44[b]		7	20.3	4.94[b]	
AV05(AD48)	1/4"	1400	66.5	35	86.0	13		7	28.8[c]	4.03	

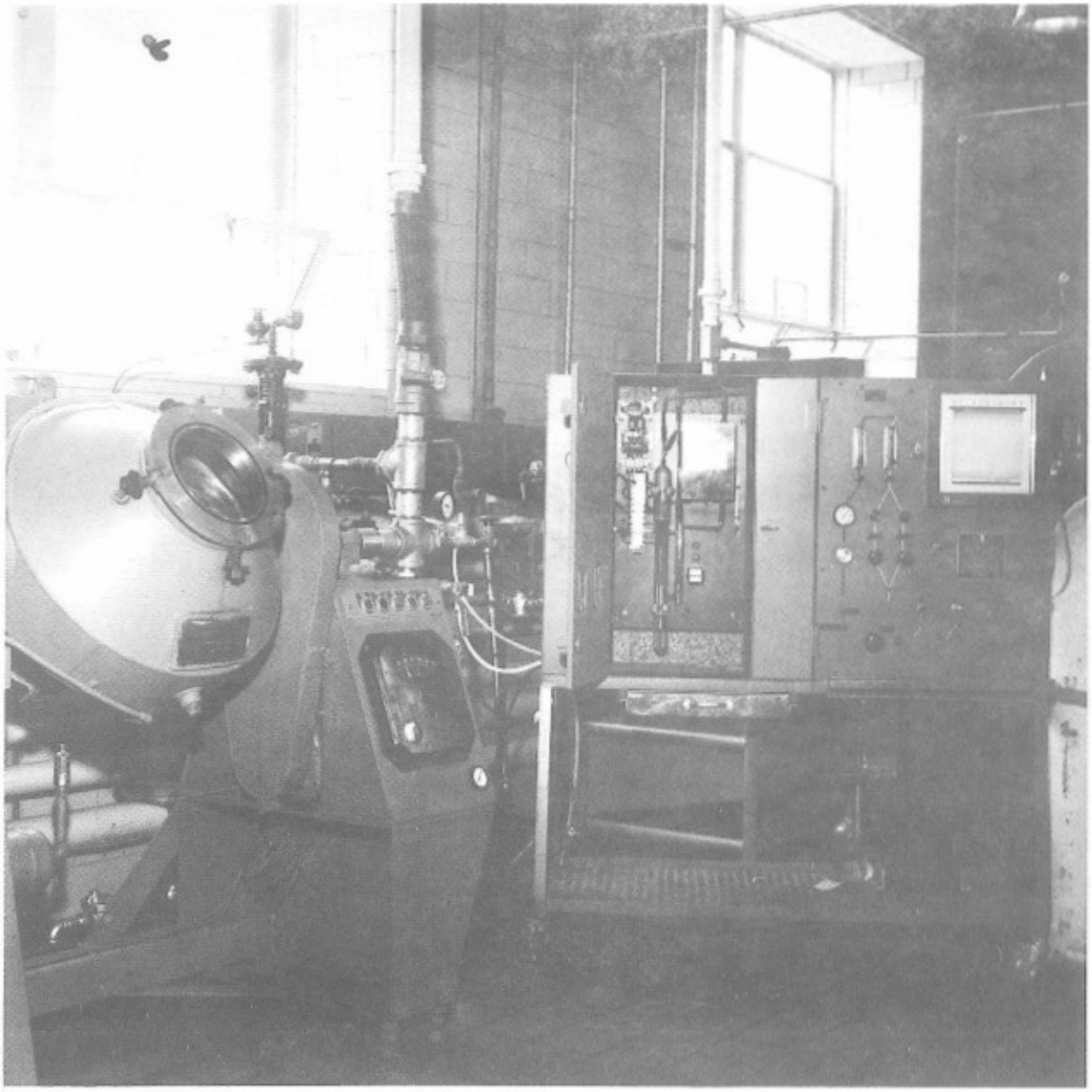
a) air-dried without break for equilibration, longer drying time required.

b) larger dices dry more slowly in the second and third stages.

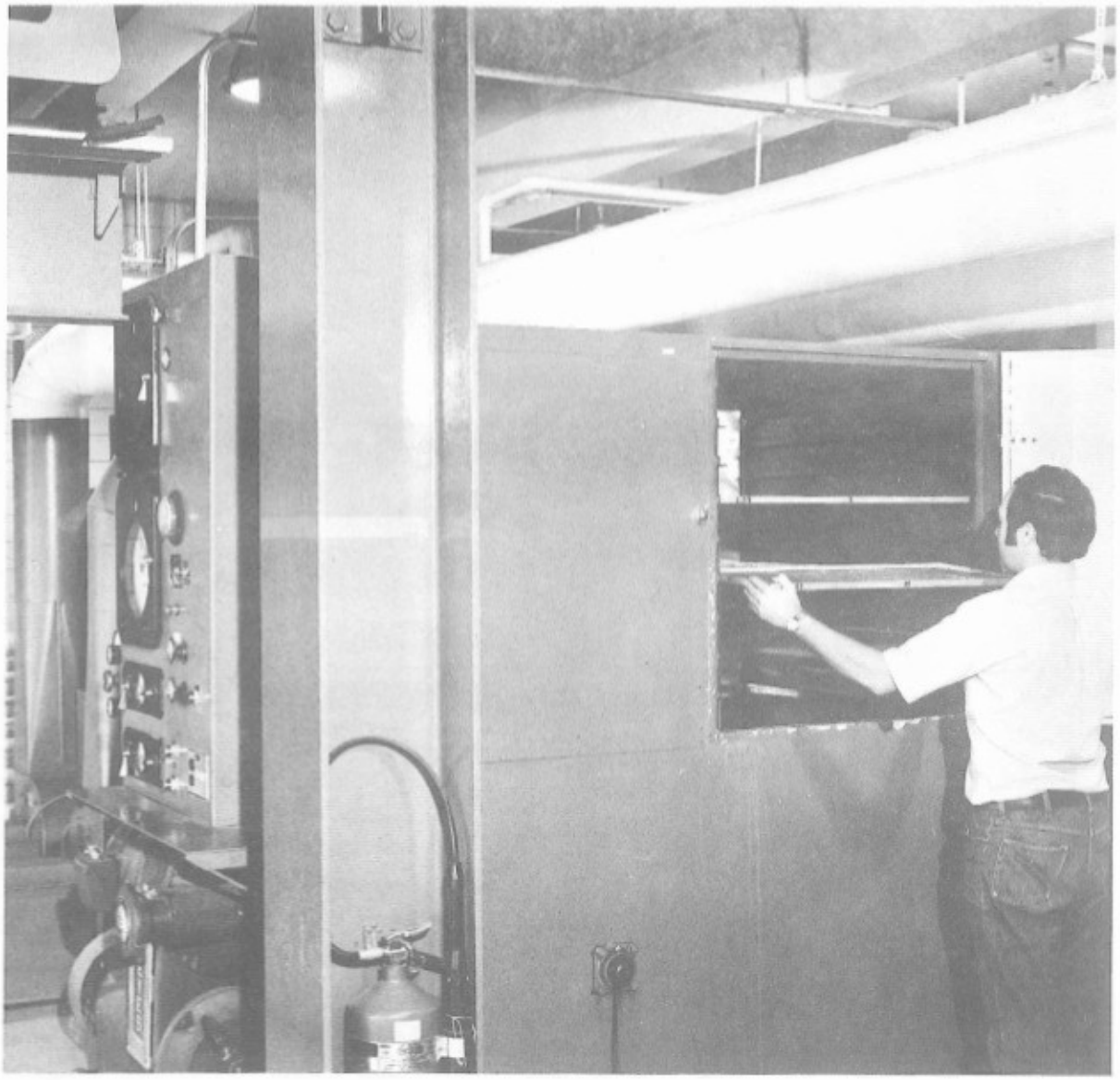
c) smaller dices pick up greater proportion of water during sulfite pretreatment - are wetter entering the dryer.

4A.4 PHOTOGRAPHS OF EQUIPMENT

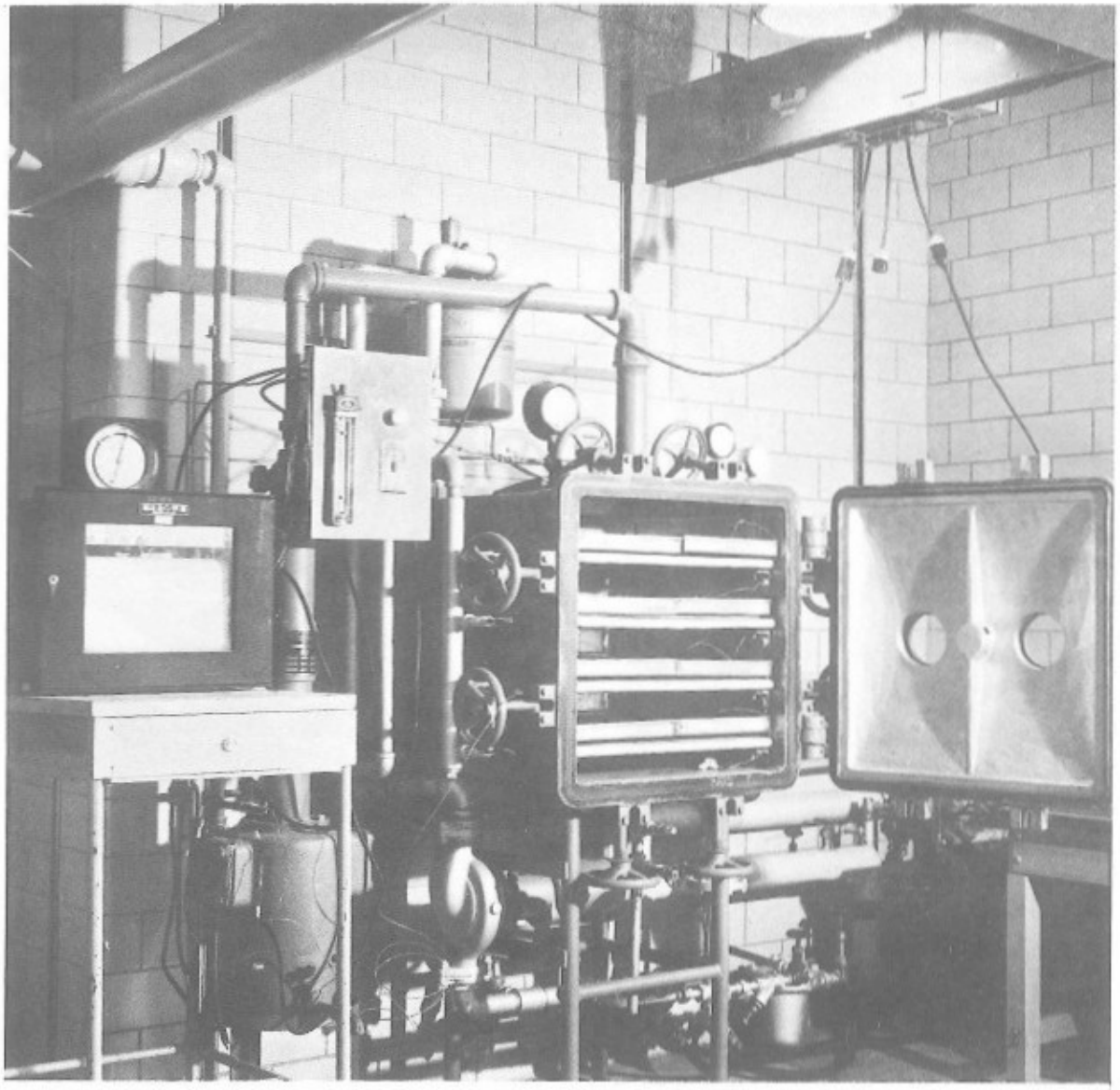
Fig. No.	Caption
4A.4.1	Vacuum tumble-dryer used for treating fresh or partially-dried lots with mixtures of SO_2 in air, and the apparatus for metering and analyzing for SO_2.
4A.4.2	Cabinet-type recirculating air-dryer.
4A.4.3	Vacuum shelf-dryer with recording potentiometer used to monitor shelf and product temperatures.
4A.4.4	Freeze-dryer.
4A.4.5	Glove box used to pack samples under nitrogen.
4A.4.6	Laboratory apparatus for the purge-type determination of SO_2
4A.4.7	Apparatus for determining headspace oxygen in rigid containers



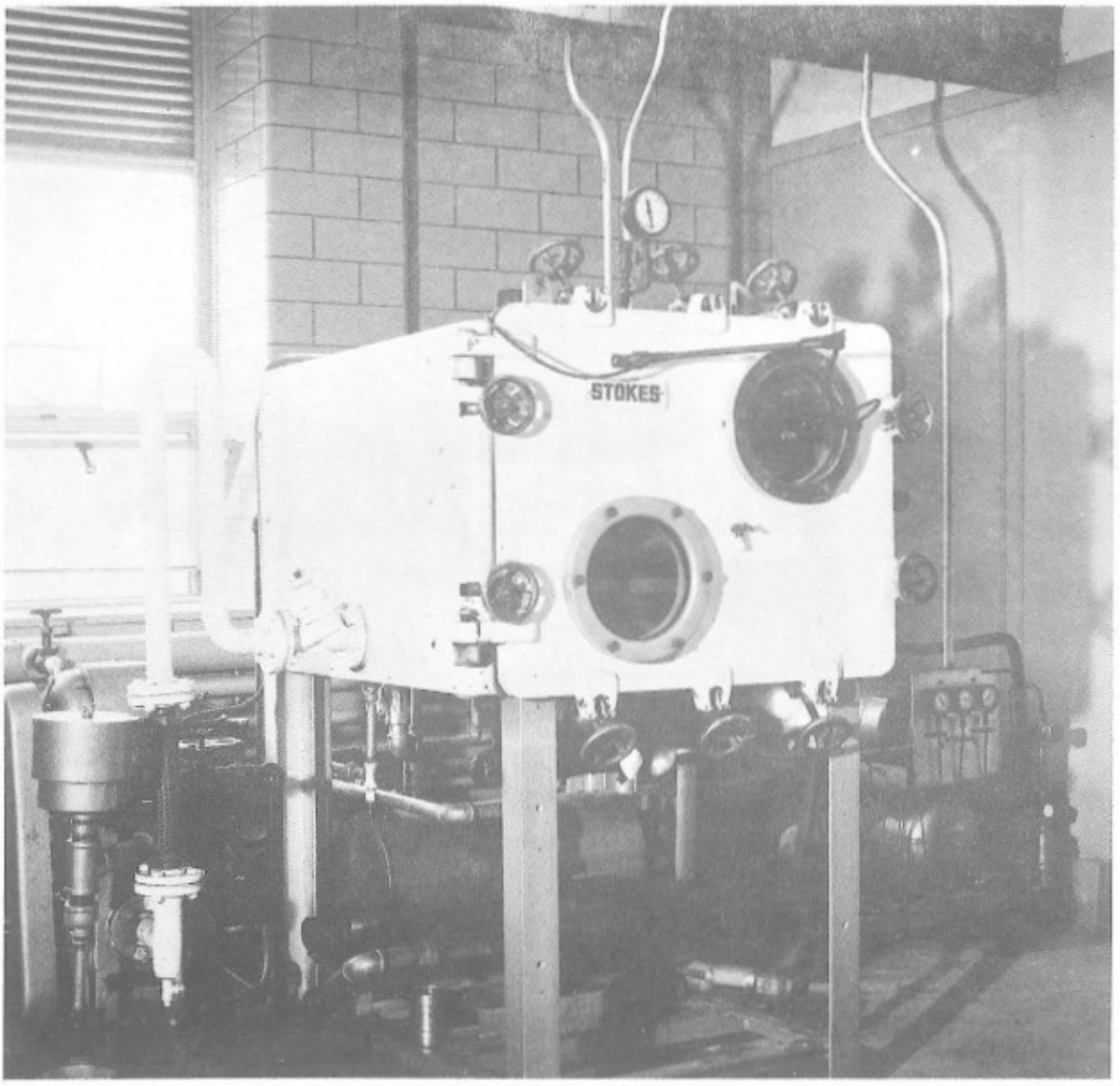
4A.4.1 Vacuum tumble-dryer used for treating fresh or partially-dried lots with mixtures of SO_2 in air, and the apparutus for metering and analyzing for SO_2.



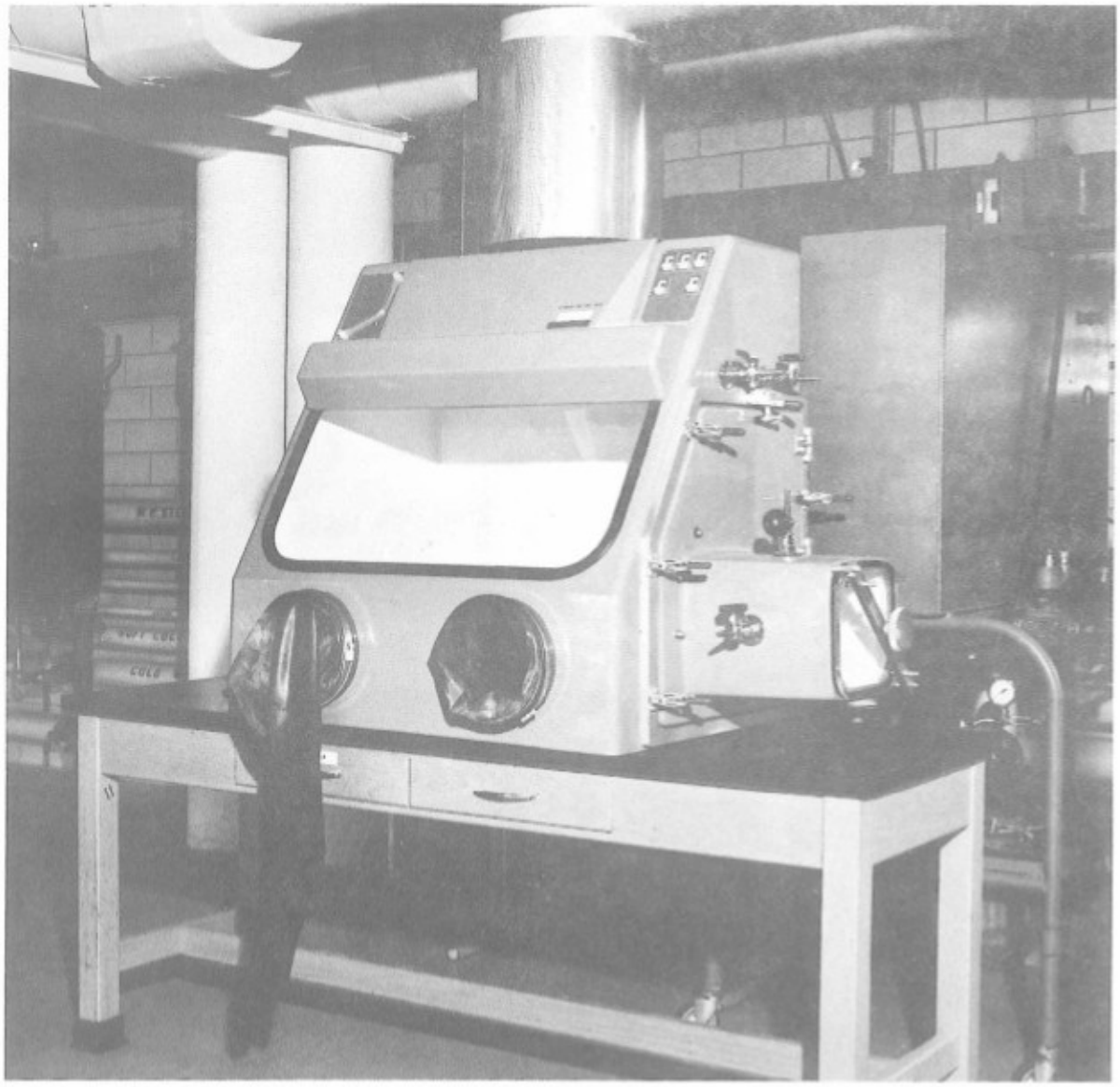
4A.4.2 Cabinet-type recirculating air-dryer.



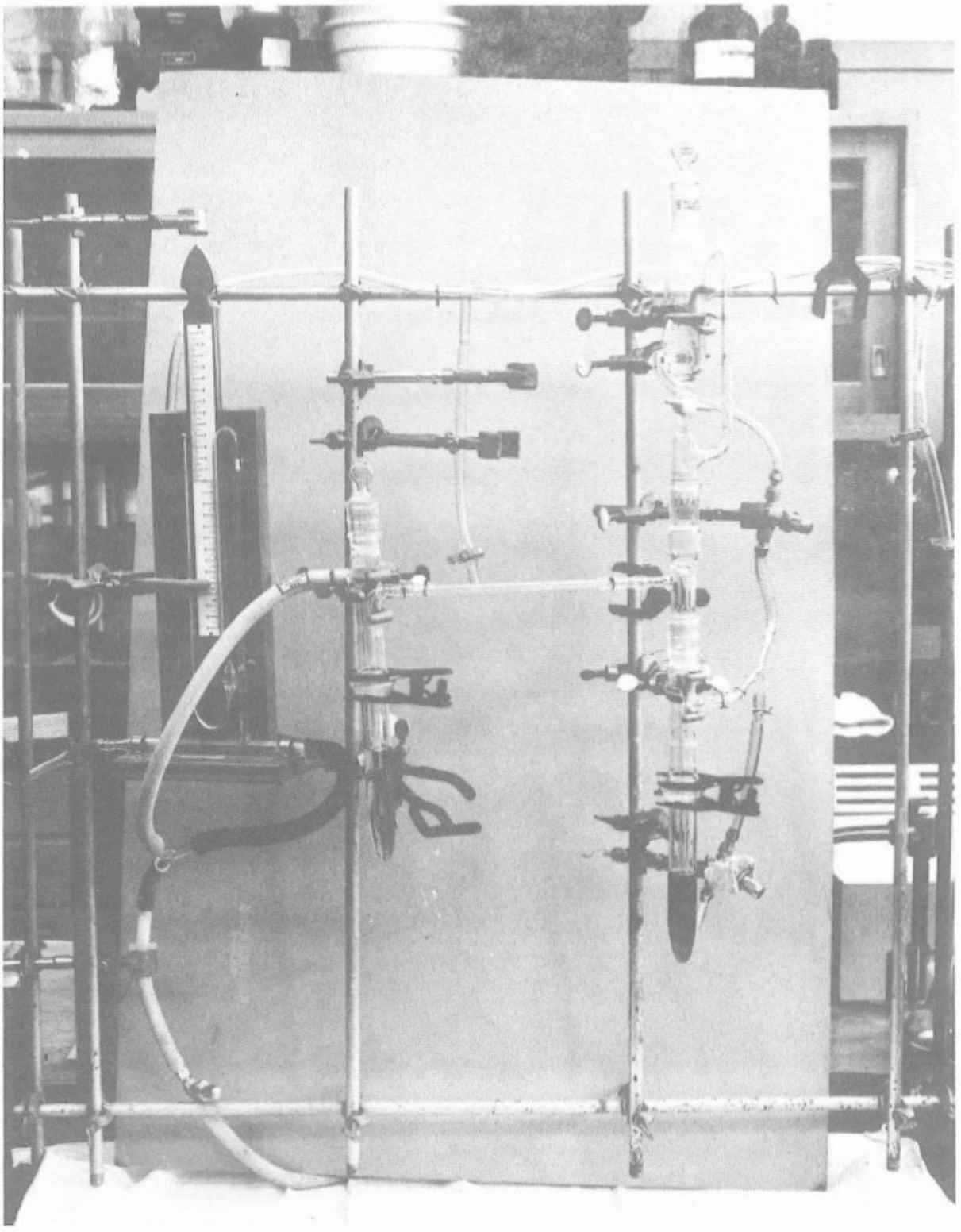
4A.4.3 Vacuum shelf-dryer with recording potentiometer used to monitor shelf and product temperatures.



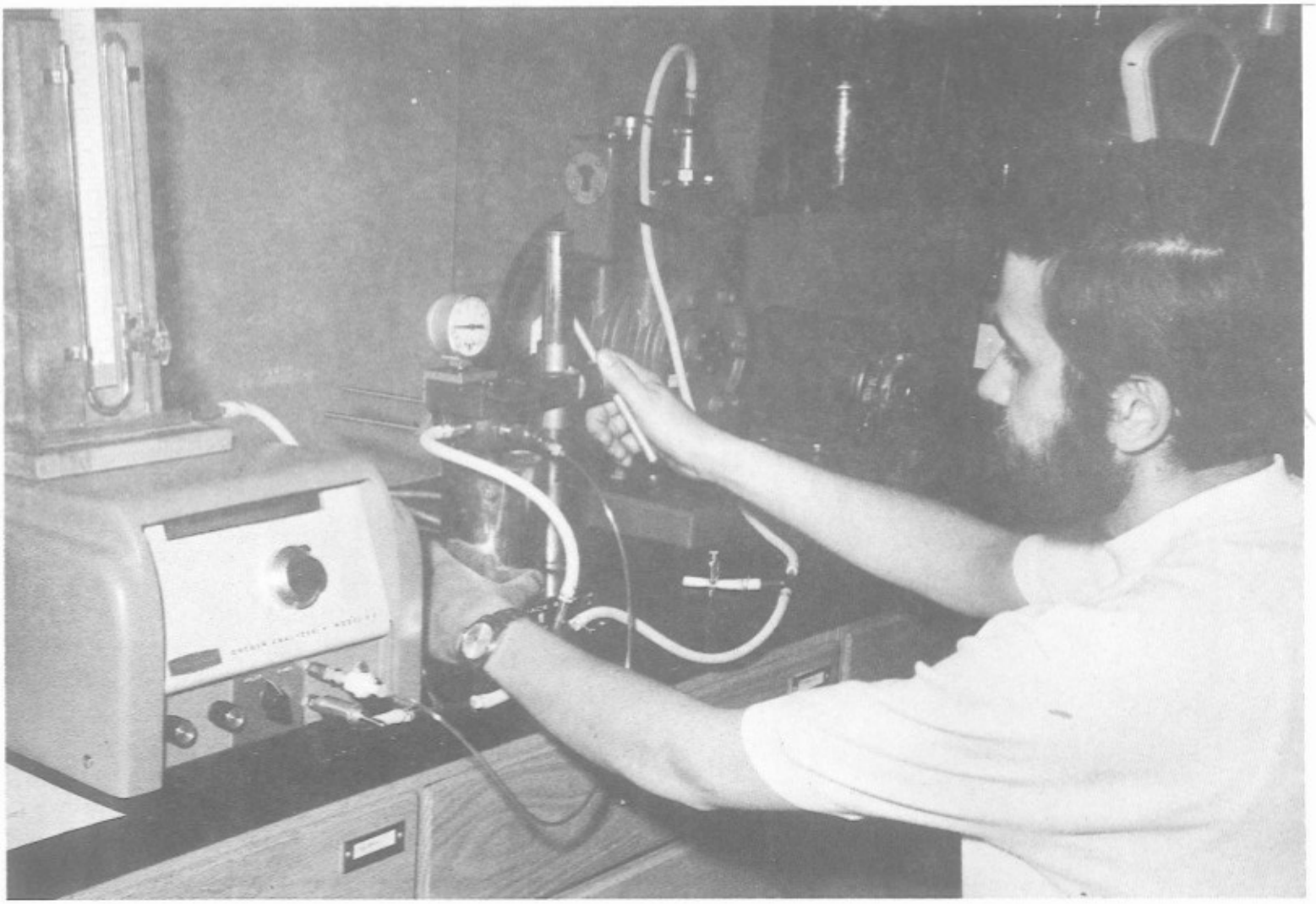
4A.4.4 Freeze-dryer.



4A.4.5 . Glove box used to pack samples under nitrogen.



4A.4.6 Laboratory apparatus for the purge-type determination of SO_2.



4A.4.7 Apparatus for determining headspace oxygen in rigid containers.

4A.5 SAMPLES OF DRIED PRODUCT PROVIOED NATICK LABORATORIES AT THE CONCLUSION OF CONTRACT OAAG17-70-C-0181 8Y THE NEW YORK STATE AGRICULTURAL EXPE MENT STATION

	Treatment	No. of cans		Net wt. per can, g
CHERRIES:				
71N-C63-AD22	3% SO_2 gas @ 65% Wt. Red.	8[a]		150
C63-AV20	3% SO_2 gas @ 65% Wt. Red.	8[a]		135 (110)[b]
C58-FD20	dip after pit/5,000 ppm SO_2	20[a]		60 (45-50)[b]
C61-F021	no SO_2 treatment	20[a]		60 (45-50)[b]
	TOTAL WEIGHT, Kg		4.08	
PEPPERS:				
71N-P15-F010	dip in 4,000 ppm SO_2	22		20[b]
	TOTAL WEIGHT, kg.		.44	
APPLES:				
71NAP-A009	dip in 3,000 ppm, 3/8" slice	4		125
AD10	dip in 1,500 ppm, 3/8" slice	4		125
AV01	dip in 1,500 ppm, 3/8" slice	2		125
AV02	dip in 3,000 ppm, 3/8" slice	2		140
AV03	dip in 1,500 ppm, 3/8" slice	2		130
AV04	dip in 1,500 ppm, 1/2" dices	2		140
AV05	dip in 1,500 ppm, 1/4" dices	2		130
	TOTAL WEIGHT, kg		2.33	

a) equally divided among the four storage conditions

b) weight of product without desiccant

4A.6 DISCLAIMER ON TRADE NAMES AND MANUFACTURERS

Mention of products or equipment used by the Contractor in carrying out this research shall not be construed as an official endorsement or approval by the United States Government for their use in this or any other context. Citation of such products or equipment by trade name or manufacturer is intended soley to identify more accurately the manner in which processing steps or analyses of product quality were actually carried out.

4A.7 SELECTED BIBLIOGRAPHY

1. Acker, L. 1962. Enzymic reactions in foods of low moisture content. Adv. in Food Res. 11, 290.

2. Anon. 1964. Sulfur dioxide technical handbook. 3rd Edition. Tennessee Corporation, Industrial Chemicals Marketing Div., Atlanta.

3. Bolin, H. R. and F. P. Boyle. 1972. Effect of storage and processing on sulfur dioxide in preserved fruit. Food Prod. Devel. 6:7, B2, 84, 86.

4. Burroughs, L. F., and A. H. Sparks. 1964. The determination of the free sulphur dioxide content of ciders. Analysts 89, 55.

5. Burton, H. S., D. J. McWeeny, and D. O. Biltcliffe. 1963. Nonenzymatic browning: The role of unsaturated carbonyl compounds as intermediates and of SO_2 as an inhibitor of browning. J. Sci. Food and Agr. 14:12, 610.

6. DeEds, F. 1961. Summary of toxicity data on SO_2. Food Technol. 15:9, 18.

7. Embs, R. J. and P. Markakis. 1965. The mechanism of sulfite inhibition of browning caused by polyphenol oxidase. J. Food Sci. 30:5, 753.

8. Humphrey, R. E., M. H. Ward, and W. Hinze. 1970. Spectrophotometric determination of sulfite with 4,4'-dithiodipyridine and 5,5'-dithiobis (2-Nitrohenzoic acid). Anal. Chem. 42, 698.

9. Joslyn, M. A. and J. B. S. Braverman. 1954. The chemistry and technology of the pretreatment and preservation of fruit and vegetable products with sulfur dioxide and sulfites. Adv. in Food Res. 5, 141.

10. Joslyn, M. A. and J. D.Ponting. 1951. Enzyme catalyzed oxidative browning of fruit products. Adv. in Food Res. 3, 5.

11. LaBelle, R. L. and J. C. Moyer. 1966. Dehydrofreezing red tart cherries Food Technol. 20, 105.

12. Marshall, R. E. 1954. Cherries and cherry products. Interscience Publishers (Div. of John Wiley & Sons), New York.

13. McBean, D. McG., A. A. Johnson, and J. I. Pitt. 1964. The absorption of sulfur dioxide in fruit tissue during drying. Food Technol. 19:9, 1447.

14. McBean, D. McG. 1971. Recent advances in dehydration processes. CSIRO Food Preserv. Quarterly 31:3, 41.

15. Paul, F. Zuverlassige Bestimmungsmethoden fur Aldehyd und schwefelige Saure in Wein und Fruchtsaften unter Verwendung des apparates von Lieb

und Zacherl. Mitt. Rebe u. Wein, Klosterneuberg, 1954, 4: 225.

16. Paul, F. 1958. Die alkalimetrische Bestimmung der freien, gebundenen und gesamten schwefeligen Saure mittels des apparates von Lieb und Zacherl. Mitt. Rebe u. Wein, Klosterneuberg 8: 21

17. Pentzer, W. 1955. Dried and dehydrated fruits are semiperishable - Proceedings, establishing optimum conditions for storage and handling of semiperishable subsistence items conference. (H. E. Goresline, N. J. Leinen, and E. M. Mrak, Editors). Dffice of the GM General, Res. and Development Div., Washington, D. C. p. 81.

18. Ponting, J. D. and G. Johnson. 1945. Determination of sulfur dioxide in fruits. Ind. and Eng. Chem., Anal. Ed., 17, 682.

19. Ponting, J. D. 1960. The control of enzymatic browning of fruits. Symposium on foods: Food Enzymes. (H. W. Schultz, Ed.). The Avi Publishing Co., Westport, CT.

20. Powers, M. J., R. Jackson, P. W. Kilpatrick, J. E. Brekke, and D. W. Sanshuck. 1958. Low moisture red sour pitted cherries. Food Technol. 12:11, 610.

21. Prater, A. N., C. M. Johnson, and M. F. Pool. 1944. Determination of sulfur dioxide in dehydrated foods. Ind. and Eng. Chem. Anal. ed. 16, 153.

22. Rahman, A. R. 1969. Sulfite in processed fruits and vegetables. Proceedings of a conference at Natick Laboratories of U.S. Army,

23. Ripper, M. J. 1892. J. prakt. Chem., 36: 428.

24. Schroeter, L. C. 1966. Sulfur-dioxide - applications in foods, beverages, and pharmaceuticals. Pergammon Press, Dxford.

25. Stadtman, E. R. 1948. Nonenzymatic browning in fruit products. Adv. in Food Res. 1, 325.

26. Talburt, W. F., C. E. Hendel, and R. R. Legault. 1954. Desiccating in the package. Food Eng. 26:4, 79.

27. Van Ardsdel, W. B. 1963. Food Dehydration, Vol. 1. Avi Publishing Co., Westport, Ct.

28. Van Ardsdel, W. B. and M. J. Copley. 1964. Food Dehydration. Vol. II. The Avi Publishing Co., Westport, Ct.

29. Wiegand, E. H., E. M. Litwiller, and M. B. Hatch. 1945. Dehydration of cherries and small fruits. Fruit Prod., J. 25:1, 9.

4A.8 ACKNOWLEDGEMENTS

The authors are pleased to acknowledge the technical assistance of Robert W. Kime and Felipe Pietrini L., who were especially involved in carrying out the experimental program, and also John F. Kenny, Leon R. Lind, Joanne E. Whitcombe, and Edward E. Woodams. The mechanical assistance of Louis M. Schult, Herbert C. Rietmann, and Paul Nelson and the administrative help of Ruth M. Bowers, Rocco J. Polimeni, Jr. and Joseph G. Ebel are also appreciated. Thanks are also due the Contracting Officer, Edward J. Corbett, and the Project Officer, Abdul R. Rahman of the Natick Laboratories, for, respectively, administering the project and providing valuable consultations at intervals during its course.

Special attention is called to the Thesis entitled, "Sulfiting Treatments for the Dehydration of Red Tart Cherries", filed with Cornell University by Felipe Pietrini in September 1972 in partial satisfaction of the requirements for a Master of Science degree in the field of Food Science. His research was carried out entirely within the scope of and as an important contribution to this project under the supervision of the authors.